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# Integration SDG Principles into Project-Based Science Learning to Increase Student ' Enviromental Awareness

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**ABSTRAK**

Penelitian ini menganalisis integrasi prinsip Science for Global Sustainability (SFG) ke dalam Project-Based Science Learning (PBSL) untuk meningkatkan kesadaran lingkungan siswa. Dengan menggunakan pendekatan deskriptif kualitatif yang didukung oleh analisis literatur, penelitian ini mengevaluasi rasional pedagogis dan ekologis dari model SFG-PBSL, efektivitas mekanisme perubahan perilaku yang dihasilkannya, serta tantangan dalam penerapannya pada tingkat kelas dan institusi. Hasil penelitian menunjukkan bahwa tanpa nilai-nilai yang berorientasi pada keberlanjutan, PBSL mampu menghasilkan keterlibatan ilmiah, namun gagal mendorong perilaku ekologis jangka panjang. Sebaliknya, integrasi SFG membangun keterkaitan yang jelas antara pengetahuan ilmiah, tanggung jawab moral terhadap lingkungan, dan praktik berkelanjutan melalui kegiatan inkuiri berbasis data, refleksi, dan aksi. Analisis ini menunjukkan bahwa SFG berperan penting dalam mentransformasi PBSL dari pedagogi yang bersifat teknis semata menjadi suatu kerangka pembelajaran yang mampu membentuk identitas ekologis siswa. Penelitian ini merekomendasikan perancangan ulang kurikulum, pengembangan profesional guru, serta kolaborasi antara sekolah dan komunitas untuk mempertahankan pendekatan pembelajaran ini.

**Kata Kunci:** aksi ekologis; kesadaran lingkungan; PBSL; SFG; identitas keberlanjutan

**ABSTRACT**

*This study analyzes the integration of Science for Global Sustainability (SFG) principles into Project-Based Science Learning (PBSL) to enhance students' environmental awareness. Using a qualitative descriptive approach supported by literature analysis, this research evaluates the pedagogical and ecological rationale of the SFG-PBSL model, the effectiveness of its behavioral change mechanisms, and the challenges surrounding its implementation at classroom and institutional levels. Findings indicate that without sustainability-oriented values, PBSL produces scientific engagement but fails to promote long-term ecological behavior. In contrast, integrating SFG fosters explicit links between scientific knowledge, moral responsibility for the environment, and sustainable practices through data-driven inquiry, reflection, and action. The analysis demonstrates that SFG is essential to transform PBSL from a purely technical pedagogy into a framework capable of shaping students' ecological identities. The study recommends curriculum redesign, teacher professional development, and school–community collaboration to sustain this learning approach.*

***Keywords:*** *ecological action; environmental awareness; PBSL; SFG; sustainability identity*

## INTRODUCTION

Science education in the 21st century requires students to not only understand theoretical concepts, but also to have ecological awareness and scientific thinking skills that are relevant to global environmental challenges. Schools continue to face the need to develop a generation capable of critical thinking, data-based decision making, and demonstrating real ecological behavior in everyday life. Project-Based Science Learning (PBSL) is considered one of the most effective pedagogical approaches to improving science literacy and environmental awareness, as it involves students in authentic investigations based on real problems in their communities that require direct scientific action and evidence-based reflection. This approach has been shown to increase student engagement because learning takes place through meaningful research activities, rather than simply conveying theoretical information, as demonstrated by Basche et al. (2016).

The project-based learning model also provides space for students to connect scientific knowledge with relevant environmental issues at the local to global levels. As issues such as the climate crisis, pollution, and biodiversity loss demand increasing attention in education, schools need a curriculum approach that focuses on real action, not just passive awareness. Research by Kricsfalusy et al. (2018) shows that integrating project-based learning and problem solving in an environmental context can increase students' awareness of sustainability and encourage behavioral change. In the Indonesian context, the urgency of environmental education has also increased due to consumption patterns and climate change that directly impact local ecosystems and quality of life, so science education must be able to foster ecological awareness from elementary and middle school age.

The integration of SFG (Science For Global Sustainability) principles is relevant to the development of PBSL because it not only teaches scientific inquiry but also positions science as an instrument for global sustainability. SFG involves a value orientation towards environmental conservation as well as scientific data-based activities to create sustainable ecological solutions. Strachan et al. (2019) show that project-based education focused on sustainability encourages students to develop an ecological identity and a sense of social responsibility. Thus, the integration of SFG into PBSL not only functions as a learning strategy but also forms a value framework that connects science with moral responsibility for environmental sustainability.

Indications of the effectiveness of PBSL in encouraging deep learning are also reinforced by Miller and Krajcik (2019), who reveal that project-based science activities enable learners to construct meaningful scientific knowledge through experimental design, data investigation, and scientific argumentation. When scientific activities are systematically combined with environmental issue analysis, learning produces a comprehensive scientific experience: scientific thinking, ecological action, and reflection on ecological impacts. Mardiyah (2024) asserts that science learning can instill environmental awareness through the integration of sustainability values without reducing scientific rigor.

However, the integration of environmental values into learning does not always have a direct effect on ecological behavior. Nainggolan et al. (2020) show that the success of PBSL is highly dependent on learning design, teacher scaffolding, and the clarity of project outputs. This indicates that PBSL will only be effective if learning is designed systematically and oriented towards real environmental action. Mukti (2025) also emphasizes that an increase in awareness of climate change among students occurs when projects require real scientific application and not just research reports.

However, there is still a gap between the improvement of science literacy and the improvement of ecological attitudes. Bukhari et al. (2023) showed that the improvement of science literacy is not necessarily directly proportional to the formation of environmental awareness without contextual involvement. In other words, science content does not automatically shape ecological character, so the integration of SFG into PBSL is important to connect science learning with value-based ecological actions. Putri's (2025) research supports these findings by showing that learning involving activities based on local environmental issues is more effective in shaping ecological behavior than lecture-based learning.

The research gap in this topic arises from the lack of clarity in the explicit integration of SFG principles into the PBSL structure. For example, Basche et al.'s (2016) research focused on student engagement in environmental projects but did not integrate sustainability value principles into the learning design. Kricsfalusy et al.'s (2018) research assessed the effectiveness of project-based courses for environmental studies but did not directly evaluate the implications of SFG principles on the formation of ecological awareness in students. Furthermore, the research by Miller and Krajcik (2019) reviews deep learning in PBSL, but does not link deep scientific learning with environmental sustainability mindset. These three studies have not explored how the explicit integration of SFG into PBSL can improve students' environmental awareness theoretically and practically.

The novelty of this research lies in its attempt to formulate the concept of integrating SFG principles into PBSL not only as a pedagogical technique but also as a meaningful learning experience for building ecological identity. The purpose of this study is to analyze how the integration of SFG principles in PBSL can increase students' environmental awareness through contextual and ecologically sustainable project-based science learning.

## METHOD

This study uses a descriptive qualitative approach with literature-based conceptual analysis to explore the role of integrating SFG principles into PBSL in increasing students' environmental awareness. The qualitative approach is relevant because it allows for an in-depth examination of theory, learning design, and the implications of ecological values in science learning. Descriptive qualitative design is widely used to examine project-based education phenomena because it provides an analytical foundation for systematically interpreting concepts based on academic literature data. This approach refers to the methodological explanation in the book Qualitative Inquiry and Research Design by Creswell and Poth (2018), which explains that qualitative research aims to construct a holistic conceptual understanding through the interpretation of scientific sources.

The data sources for this study consisted of reputable journal articles in the fields of project-based learning, science education, and environmental education. The literature was analyzed using content analysis techniques to compare, identify patterns, and draw conceptual meanings related to environmental awareness and the integration of SFG in PBSL. The analysis procedure was carried out through the stages of data reduction, concept categorization, and conclusion drawing to then formulate a model for integrating SFG principles into PBSL. Conceptual validity was achieved through traceable arguments and coherence between literature findings as recommended by Creswell and Poth (2018) in academic qualitative research standards.

## RESULTS AND DISCUSSION

### The Rationality of Integrating SFG Principles into Project-Based Science Learning: A Critical Analysis of Pedagogical and Ecological Foundations

The fundamental question that must be examined in this study is not simply whether Project-Based Science Learning (PBSL) can increase environmental awareness, but whether the internal structure of PBSL is epistemologically strong enough to form an ecological identity without the integration of explicit values such as SFG. If PBSL is designed only as a medium for engagement and scientific experimentation, the results will be limited to scientific engagement without a responsibility-oriented sustainability mindset. This is evident from the research by Basche et al. (2016), which noted an increase in student involvement in environmental projects but did not conclude that there was a permanent transformation in ecological behavior. This fact shows that the success of PBSL should not be measured solely in terms of laboratory activities or projects but must be linked to changes in ecological disposition.

Previous studies assumed that PBSL was inherently capable of increasing environmental awareness, but this approach was overly optimistic. Kricsfalusy et al. (2018) assessed that project-based learning was effective in building sustainability awareness, but the variables studied focused on course outcomes rather than the long-term sustainability of behavioral change. Meanwhile, Strachan et al. (2019) emphasized that embedding sustainability in the curriculum can encourage students to build a sustainability identity, but the study showed that success only occurs when a sustainability orientation is designed as a core structure, not an optional element. In other words, without explicit value integration, PBSL only produces scientific literacy without ecological conscience.

Thus, the epistemological issue is how students construct scientific meaning in the context of sustainability. PBSL guides students to think critically through experiments, but the data interpretation stage often stops at scientific reasoning and fails to connect it to the ecological context. Miller and Krajcik (2019) explain that deep learning in PBSL occurs when students can design solutions based on their own data. However, deep scientific learning is not necessarily synonymous with environmental ethical reasoning. Therefore, the SFG principle is needed as a value architecture to ensure that scientific interpretation is directed towards ecological reflection. Thus, SFG is not merely an addition but an epistemic prerequisite for PBSL to produce ecological, rather than mechanical, learning.

Pedagogically, the integration of SFG in PBSL functions as an internal mechanism to affirm the relationship between scientific data and ecological decisions. Mardiyah (2024) shows that the integration of sustainability values in science education gives rise to ecological moral reasoning without reducing scientific rigor. This finding refutes concerns that the integration of values will reduce scientific objectivity. In fact, without sustainability values, scientific interpretation has the potential to become an exploitative instrument if it is not directed towards an ethical framework. This means that arguments against the integration of values in science education are irrelevant in the context of 21st-century education because ecological challenges require scientific knowledge accompanied by moral and social control mechanisms.

Furthermore, SFG integration can also address the contradiction between increased science literacy and stagnant ecological behavior. Bukhari et al. (2023) found that increased science literacy does not automatically increase environmental awareness because students understand scientific concepts but do not find their practical and emotional relevance. Putri (2025) proved that learning based on local environmental activities produces stronger ecological attitude changes than learning based on theoretical information. Thus, the main hypothesis in this discussion is that SFG functions as an interpretive bridge between scientific knowledge and ecological choices. Without SFG, PBSL only produces knowledge; with SFG, PBSL produces ecological dispositions.

Thus, the success of project-based science learning does not lie in the complexity of experiments or learning technology, but in the extent to which scientific projects are directed to encourage students to make data-based ecological decisions. Mukti (2025) emphasizes that increased climate awareness is only achieved when projects demand real scientific application, not passive observation. Thus, PBSL that integrates SFG challenges the conservative learning paradigm and positions students as scientist-citizens, not science consumers. Therefore, the integration of SFG into PBSL is not only ideal but also a pedagogical and ecological imperative. Without such integration, PBSL fails to respond to the demands of contemporary environmental education.

Furthermore, it should be emphasized that the integration of SFG into PBSL is not only a strategy to improve science learning outcomes, but also a repositioning of the science education paradigm towards a *responsible-driven* learning model. Research by Strachan et al. (2019) shows that students only exhibit consistent sustainable behavior when they view science not as a technical activity, but as part of their moral and social identity. This indicates that the absence of sustainability values in project design limits the potential of PBSL in shaping sustainable environmental habits. Thus, the integration of SFG functions as an ideological control that ensures that the design and interpretation of scientific activities are not ecologically neutral but pro-sustainability. This view also criticizes the old pedagogical perspective that assumes science must be value-free, because in the context of the global ecological crisis, the liberation of science from values actually weakens the role of education as a moral controller of society.

Another argument that reinforces the urgency of SFG integration in PBSL is that without a foundation of sustainability, scientific concepts can be used to reinforce unsustainable practices. Miller and Krajcik (2019) emphasize that deep scientific learning enables students to modify the environment by improving technology, but without sustainability values, students may develop solutions that are short-term efficiency but have a negative impact on the ecosystem. In this context, SFG becomes a normative filter so that the design of scientific solutions is directed towards long-term sustainability principles, not just short-term effectiveness. This approach is also in line with Mardiyah's (2024) findings, which show that scientific understanding will only create environmental awareness if accompanied by the internalization of ecological values. This means that SFG not only supports PBSL but also prevents potential ethical deviations resulting from the use of scientific concepts without a sustainability orientation.

**Effectiveness of the Integration Model: Criticism of Behavior Change Mechanisms and Analysis of SFG-Based Learning Outputs**

One of the most crucial issues in environmental education is that ecological behavior change does not automatically arise from scientific understanding. Therefore, the effectiveness of SFG integration into PBSL must be tested not only at the cognitive level but also at the behavioral mechanism level. Hanif et al. (2024) show that project-based learning only has a significant impact on sustainability understanding if students interpret the results of their investigations in an ecological context. Without a value context, learning even has the potential to create a gap between knowledge and responsibility. This means that scientific projects must be designed so that students feel responsible for the ecological consequences of the decisions they make during their investigations.

But does ecological responsibility grow as an automatic result of investigation? Not always. Kricsfalusy et al. (2018) revealed that field experiences and project-based activities are only effective if students are asked to analyze sustainability implications, not just write academic reports. In other words, *ecological transformation* requires instruction that demands students assess the ecological impact of their scientific choices. SFG supports this demand by ensuring that scientific activities are not only experiment-oriented, but also sustainability-oriented. Thus, the integration of SFG plays a corrective role to the weakness of PBSL, which places too much emphasis on scientific mechanisms without moral reflection.

The effectiveness of SFG integration can also be understood through the analysis of epistemic, value, and behavioral components in learning as follows:

| Component | Scientific Activity | Sustainability Value | Behavioral Output |
|---|---|---|---|
| Problem Identification | Observing and defining environmental problems | Critical awareness of ecological risks | Recognition and prioritization of environmental issues |
| Investigation | Conducting experiments and data collection | Ethical care of natural resources | Decision-making that avoids harmful ecological consequences |
| Data Analysis | Interpreting findings and validating evidence | Reflection on environmental implications | Ability to justify pro-environmental action |
| Project Output | Designing an applicable scientific solution | Long-term ecological responsibility | Active participation in sustainability actions |
| Reflection | Analysing scientific and personal learning impact | Construction of ecological identity | Formation of stable pro-environmental habits |

The table shows that the integration of SFG into PBSL shifts learning from the “knowing” paradigm to the “acting on knowledge” paradigm. This contrasts with the old environmental education tradition, which assumes that knowledge leads to attitudes. Instead, the SFG-PBSL model states that ecological behavior is formed through a combination of epistemic judgment, value internalization, and behavioral practice. This approach resonates with the findings of Strachan et al. (2019), which show that ecological identity develops through reflective experiences that combine emotional, moral, and scientific dimensions.

The effectiveness of this integration model also depends on emotional and social factors. Pratama et al. (2025) show that emotional involvement in aesthetic science activities can reduce learning anxiety and increase student comfort in environmental activities. This illustrates that the formation of ecological awareness does not only take place through scientific rationality, but also through affective engagement. In addition, research by Ahmad et al. (2023) notes that involvement in sustainability projects increases student participation in school environmental actions, confirming the social dimension as a reinforcer of ecological behavior.

Behavioral change is also influenced by students' agentic identity as part of the environmental community. Munfarikhah et al. (2025) found that learning that integrates environmental values creates a sense of moral connectedness between students and the ecological community. This is important because long-term ecological actions do not depend on teacher instruction, but on the connectedness of students' collective identity with environmental sustainability. Maestrales' (2024) findings show that the integration of technology in project-based learning opens up space for students to communicate scientific findings in the form of data-driven sustainability campaigns, expanding the impact to the social sphere.

Therefore, the reason why the integration of SFG in PBSL is more effective than traditional PBSL is not only because it teaches ecological content, but because it institutes a learning pattern that forces the integration of scientific rationality, sustainability values, and collective agency. Without this integration, PBSL functions only as a pedagogical technique; with this integration, PBSL functions as an *ecological formation framework*. Thus, the SFG-PBSL integration model is not merely an alternative approach, but a conceptual mechanism to ensure that scientific learning produces stable and sustainable ecological behavioral change.

**Challenges and Implications of Implementing SFG Integration in Project-Based Science Learning in Schools**

Although integrating SFG principles into PBSL offers a strong conceptual framework for creating sustainability-oriented science learning, its implementation in schools is not straightforward. The first challenge arises from teachers' pedagogical competence in translating sustainability values into scientific project structures.

Nainggolan et al. (2020) show that the success of project-based learning is highly dependent on learning design and teacher scaffolding. Without proper design, learning simply turns into project activities without epistemic or ecological direction. Some teachers are accustomed to assessing learning success based on the success of product output, whereas the SFG approach requires learning evaluation based on ecological reflection and scientific thinking processes. This obstacle shows that teachers need new curriculum literacy that not only understands scientific experiments but also enables them to guide students in integrating the ecological consequences of scientific decision-making.

The second challenge relates to the school culture, which still places science learning in a technical rather than an ecological paradigm. Science learning in schools often pursues cognitive targets such as material mastery, so that sustainability values are considered secondary. Yusupova et al. (2025) emphasize that the development of sustainability awareness in project-based learning only occurs if educational institutions are aware that sustainability is a curriculum goal, not an optional theme. When schools still view the environment as merely an additional topic or theme, the integration of SFG values in PBSL will lose its structural strength. Thus, the implementation of SFG integration requires institutional support in the form of consistent curriculum, evaluation, and academic culture policies.

Another challenge that is rarely studied is the gap between project experiences at school and the environmental reality outside of school. Mukti (2025) shows that environmental learning has a greater impact if students are involved in projects directly related to climate change in their region. Without contextual connection, SFG integration will only become abstract classroom instruction and will not create emotional or social experiences. Putri (2025) supports this finding by proving that contextual activities result in stronger ecological attitudes than information-based learning alone. This means that SFG integration must encourage students to engage with local issues so that their ecological identity grows through social experience and not just through moral or scientific instruction.

Beyond pedagogical, institutional, and contextual challenges, there is another epistemological issue: how to ensure that behavioral transformation does not stop after the project ends. Ahmad et al. (2023) note that participation in environmental action increases during the project, but there is little evidence of behavioral sustainability after academic activities end. In this context, SFG integration requires a long-term reflection phase in PBSL to encourage students to repeatedly assess ecological impacts. Hanif et al. (2024) show that reflection after scientific inquiry is a key determinant of the formation of sustainability concepts in students. If reflection is considered optional, learning will fail to shape long-term behavior.

However, these challenges can be turned into opportunities through curriculum redesign. Maestrales (2024) shows that integrating technology into PBSL allows sustainability actions to be extended to public platforms through the publication of experimental results in the form of data-driven digital campaigns. This approach strengthens ecological identity while creating a system of social empowerment because students not only create solutions but also communicate them to the community. Furthermore, Munfarikhah et al. (2025) emphasize that education that connects students with ecological communities creates a sense of collective social responsibility, so that scientific projects do not end with reports but result in sustainable action through social networks.

Thus, the integration of SFG in PBSL requires implementation strategies at the classroom, school, and community levels. Without this systemic support, learning will only produce short-term academic products without solid ecological behavioral change. However, if all elements are designed in harmony, the SFG-PBSL integration model has the potential to become a science education framework that not only builds scientific literacy but also gives birth to a generation with a stable ecological identity and commitment to sustainability.

## CONCLUSION

Project-based science learning will only become an instrument of ecological transformation if the principles of SFG are structurally integrated into the scientific inquiry process, project design, evaluation, and reflection. This integration has been proven to transform the function of PBSL from a technical learning approach to a pedagogical framework that instills ecological responsibility through real scientific experiences. Conceptual analysis in this study shows that SFG integration enables PBSL to unite scientific rationality, sustainability values, and ecological identity, which are manifested in changes in student behavior, not just an increase in knowledge literacy. Learning becomes an arena where students practice making data-based ecological decisions and engage in sustainability actions that are connected to their social lives.

Based on these findings, it is recommended that schools place sustainability as the core objective of science learning, not merely a curricular theme. Teachers need to receive training to design scientific projects that link experiments with ecological consequences. Reflection needs to be standardized as a mandatory component in PBSL to ensure long-term behavioral change. Schools also need to build collaborations with environmental communities so that scientific projects produce sustainable social impacts. With such structural support, the integration of SFG into PBSL can become a systemic foundation for science education that not only teaches knowledge but also prepares a generation capable of maintaining environmental sustainability scientifically and responsibly.

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