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Real-World Learning Based on SDG 6 to Enhance Students' Systems Thinking in Nature Schools

Ajeng Niamul Maula[1], Aa Juhanda[2*], Jujun Ratnasari[3], Ridwansyah[4]
[1,2,3]Biology Education Study Program, Faculty of Teacher Training and Education, Universitas Muhammadiyah Sukabumi, Jl. R. Syamsudin, S.H. No. 50, Kota Sukabumi, Jawa Barat 43113.
[4]SMP Islam Fathia Kota Sukabumi, Jl. Tampomas No. 6, Cibeureum Hilir, Kec. Cibeureum, Kota Sukabumi, Jawa Barat 43165
*Corresponding author: aajuhanda@ummi.ac.id

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Abstract: *To promote sustainable development, learning must provide real-world experiences that train students to think systemically. One essential competency to be developed is systems thinking ability. This study aims to analyze the systems thinking skills of students in a nature-based school through Real-World Learning (RWL) based on Sustainable Development Goal (SDG) 6, which focuses on clean water and sanitation. A quasi-experimental method with a non-equivalent control group design was employed. The study involved 42 eighth-grade students from Fathia Nature Junior High School in Sukabumi, assigned to experimental and control groups using a non-equivalent control group design. The findings showed that the average percentage scores of the experimental class were higher than those of the control class across all indicators. The highest indicators in the experimental class were recognizing hidden dimensions and making generalizations (each at 84%), while the lowest was identifying dynamic relationships (73%). The post-test results revealed a significant difference between the two classes (Sig. = 0.000 < 0.05). This study demonstrates that SDG 6-based RWL is effective in enhancing students' systems thinking in environmental education.*

Keywords: *nature school, systems thinking, SDG 6, real-world learning, environmental pollution*

1. INTRODUCTION

Education for Sustainable Development (ESD) plays a crucial role in preparing students to respond to complex environmental challenges in the 21st century. ESD emphasizes not only conceptual understanding but also the development of competencies that enable learners to analyze problems holistically, make informed decisions, and take responsible action (UNESCO, 2017; Cebrián et al., 2020). In line with the 2030 Agenda, education is positioned as a transformative tool to support the achievement of the Sustainable Development Goals (SDGs), particularly through contextual and action-oriented learning approaches (UNESCO, 2020).

Among the 17 SDGs, SDG 6 (Clean Water and Sanitation) represents a highly relevant and urgent issue, especially in developing countries such as Indonesia. Persistent problems related to water pollution, access to clean water, and sanitation infrastructure highlight the need for early educational interventions that foster students' awareness and understanding of water-related systems (Wilujeng et al., 2019). However, addressing such issues requires more than factual knowledge; students must be equipped with the ability to understand environmental problems as interconnected systems rather than isolated phenomena.

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One of the key competencies emphasized in ESD is systems thinking, which enables learners to recognize relationships among system components, identify feedback mechanisms, and understand dynamic and temporal changes within complex systems (Ben-Zvi Assaraf & Orion, 2005). Previous studies have shown that students often struggle with systems thinking, tending instead toward linear cause–effect reasoning when analyzing environmental problems (Mambrey et al., 2020). In the Indonesian educational context, systems thinking skills are still rarely developed explicitly in science instruction, resulting in fragmented understanding and superficial problem-solving related to sustainability issues (Salsabila et al., 2024).

To address this challenge, Real-World Learning (RWL) has been identified as a pedagogical approach with strong potential to enhance systems thinking. RWL situates learning within authentic, real-life contexts, enabling students to engage directly with environmental problems through observation, investigation, and problem-solving activities (Conti & Dawson, 2022). Research indicates that RWL and project-based learning can significantly improve students' systems thinking and sustainability competencies, particularly when learning activities are linked to real environmental issues such as water pollution and wastewater management (Albareda-Tiana et al., 2018; Salsabila et al., 2024).

In recent years, several studies have highlighted the effectiveness of contextual and project-based learning approaches in fostering higher-order thinking skills, including systems thinking and critical thinking in environmental education. Research by Puspitasari et al., (2023) demonstrated that Project-Based Learning (PjBL), particularly when integrated with a flipped classroom model, significantly enhanced students' critical thinking abilities in learning about water pollution. Their findings suggest that engaging students in authentic environmental problems encourages deeper cognitive processing and the ability to analyze complex systems.

Furthermore, Khofifah et al., (2020) emphasized the importance of carefully designed assessment instruments to capture students' systems-related thinking, particularly in biology learning contexts. Their analysis of thinking-based test instruments indicates that higher-order thinking skills, such as systems and tree thinking, require explicit instructional support and appropriate evaluation strategies.

Despite these findings, existing studies predominantly examine RWL or systems thinking within conventional school settings, with limited attention to alternative educational models. Nature schools (Sekolah Alam), which emphasize experiential, outdoor, and context-based learning, offer a unique environment for implementing RWL aligned with ESD principles. Although previous research has shown that nature schools can support the development of sustainability-related competencies (Mardiana et al., 2025), empirical studies that specifically investigate the integration of RWL based on SDG 6 to enhance students' systems thinking in nature school contexts remain scarce.

This gap indicates that the potential of combining RWL, SDG 6 content, and the pedagogical characteristics of nature schools has not been sufficiently explored. Therefore, this study aims to analyze the effect of SDG 6-based Real-World Learning on students' systems thinking skills in a nature school setting, particularly in the context of environmental pollution. The novelty of this research lies in (1) the explicit integration of SDG 6 as a learning framework within RWL activities, (2) the focus on systems thinking skills measured using the comprehensive indicators proposed by Ben-Zvi Assaraf and Orion (2005), and (3) the application of this approach in a nature school environment. The findings are expected to contribute to the development of more effective ESD-oriented instructional strategies, especially for strengthening systems thinking competencies in science education.

Based on the theoretical foundations of Education for Sustainable Development (ESD), systems thinking theory, and prior empirical findings highlighting the effectiveness of contextual and real-world learning approaches, this study formulates an explicit research hypothesis to clarify its analytical direction. Real-World Learning (RWL) grounded in SDG 6 is assumed to provide authentic, problem-based experiences that foster relational, structural, and dynamic understanding of environmental systems. Through direct engagement with real water pollution issues, students are expected to

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develop stronger abilities in identifying system components, recognizing interconnections, understanding matter and energy flows, and making informed generalizations about environmental sustainability. Therefore, it is hypothesized that students who participate in SDG 6–based Real-World Learning will demonstrate significantly higher systems thinking skills compared to students who receive conventional teacher-centered instruction. Conversely, the null hypothesis states that there is no significant difference in systems thinking skills between students exposed to SDG 6–based Real-World Learning and those taught using conventional methods. This hypothesis formulation provides a clear inferential framework for testing the effectiveness of the proposed instructional approach.

2. RESEARCH METHOD

This study employed a quasi-experimental method using a non-equivalent control group design (Creswell, 2018). The research was conducted at Fathia Nature Junior High School, Sukabumi, involving two intact eighth-grade classes. Class VIII B (n = 21) was assigned as the experimental group, while Class VIII A (n = 21) served as the control group. The assignment of classes followed the school's existing academic structure and did not involve randomization.

Learning Intervention and Duration

The intervention was conducted over two instructional sessions, each with a duration of 80 minutes (2 × 40 minute periods), in accordance with the school's standard lesson schedule. During this period, the experimental group received instruction using the Real-World Learning (RWL) approach based on Sustainable Development Goal (SDG) 6, focusing on clean water and sanitation issues. Learning activities included contextual discussions, direct observation, and a practicum involving fish exposed to different water quality conditions to represent real environmental pollution phenomena.

Although the intervention was conducted over only two 80-minute sessions, the instructional design emphasized intensive and focused learning experiences that explicitly targeted systems thinking indicators. This approach aligns with previous studies suggesting that short-term, well-structured contextual interventions can effectively stimulate higher-order thinking skills when learning tasks are directly connected to real-world problems.

The duration of 80 minutes per session reflects the standard science lesson allocation in Indonesian junior high schools. The control group received conventional instruction using a teacher-centered approach, focusing on textbook explanations and question–answer sessions without explicit integration of SDG-based contextual problems.

Control of Extraneous Variables

To minimize the influence of extraneous variables, several control measures were applied. Both the experimental and control classes were taught by the same science teacher, used the same curriculum content, learning objectives, and assessment schedule, and were conducted within the same school environment and facilities. Students in both groups had comparable academic backgrounds, as they were drawn from the same grade level and school system, and had not previously received formal instruction specifically targeting systems thinking skills. These controls were applied to ensure that observed differences in learning outcomes could be attributed primarily to the instructional approach.

Research Instruments

The main instrument used in this study was a systems thinking skills test, administered as both a pretest and posttest. The test was developed based on eight systems thinking indicators proposed by Ben-Zvi Assaraf and Orion (2005), namely. To ensure clarity and measurement precision, each systems thinking indicator was operationally defined within the context of this study.

1) *Identifying system components and processes* refers to students' ability to recognize biotic and abiotic elements involved in water pollution cases and describe their basic functions.
2) *Identifying simple relationships between components* refers to the ability to explain direct cause–effect relationships between two or more system components.

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3) *Identifying dynamic relationships* refers to the ability to describe how changes in one component influence other components over time.
4) *Organizing components within a relational framework* refers to the ability to structure system elements into a coherent network showing interconnected relationships.
5) *Identifying matter flows and energy cycles* refers to students' ability to trace the movement of substances (e.g., pollutants, nutrients) and energy within the environmental system.
6) *Recognizing hidden dimensions* refers to identifying indirect, less visible, or delayed impacts within the system.
7) *Making generalizations about systems* refers to the ability to abstract principles from a specific case and apply them to broader environmental contexts.
8) *Temporal thinking* refers to students' ability to analyze past system conditions (retrospection) and predict future consequences (prospection) related to environmental pollution.

Each indicator was measured using an analytic scoring rubric ranging from 0 to 4, where higher scores indicated deeper and more integrated systems reasoning.

The instrument consisted of eight open-ended items, with each item designed to represent one indicator. For example, students were asked to analyze a case of polluted water and explain the relationships between biotic and abiotic components, predict long-term environmental impacts, and propose system-based solutions aligned with SDG 6 principles. Responses were scored using an analytic rubric adapted from Ben-Zvi Assaraf and Orion (2005), with scores ranging from 0 to 4 for each indicator.

Prior to implementation, the instrument was reviewed by two experts in science education to establish content validity. Revisions were made based on expert feedback to improve clarity and alignment with systems thinking constructs. The reliability of the instrument was examined using internal consistency analysis, which indicated acceptable reliability for research purposes.

Instrument Validity and Reliability

The systems thinking test instrument was subjected to validity and reliability testing prior to its implementation. Content validity was established through expert judgment involving two experts in biology education and one expert in educational assessment. The experts evaluated the instrument based on the relevance of items to the systems thinking indicators proposed by Ben-Zvi Assaraf and Orion (2005), conceptual accuracy, clarity of language, and suitability for junior high school students. Revisions were made according to the experts' suggestions to ensure that each item accurately represented the intended indicator.

Reliability analysis was conducted using Cronbach's Alpha coefficient to examine the internal consistency of the instrument. The results showed that the instrument achieved a Cronbach's Alpha value of $\alpha = 0.82$, indicating a high level of reliability. According to commonly accepted criteria, an alpha value above 0.70 reflects good reliability, suggesting that the instrument was consistent and appropriate for measuring students' systems thinking skills in this study.

Data Analysis

Data analysis included descriptive statistics and inferential tests. Normality and homogeneity tests were conducted to ensure that parametric analysis assumptions were met. An independent samples t-test was then applied to compare posttest scores between the experimental and control groups. In addition, normalized gain (N-gain) analysis was used to examine the magnitude of improvement in students' systems thinking skills across indicators.

3. RESULTS AND DISCUSSION

Statistical Test

The results of statistical analysis show that the learning outcome data is distributed normally and homogeneously, so that parametric tests can be performed. The t-test on the students' pretest scores found no significant difference between the experimental and control classes (Sig. = $0.408 > 0.05$), indicating the initial thinking ability of the two classes to be balanced. In contrast, independent t-tests on posttest scores showed significant differences; The average posttest score of the experimental class (≈80.67) was much

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higher than that of the control class (≈57.17) with a significance level of $p < 0.05$. This indicates that the implementation of Real-World Learning (RWL) based on SDGs-6 has a positive and significant impact on improving students' thinking skills compared to conventional learning.

Posttest Results by Indicator

Table 1 presents a comparison of posttest scores for each indicator of system thinking between the experimental and control classes. It was seen that on each indicator, the average score of the experimental class was higher than that of the control class. For example, for Indicator 2 (identifying simple relationships between system components) and Indicator 5 (identifying the matter and energy cycles in the system), the control class only achieved scores of about 63% and 61%, while the experimental class achieved about 90% on these indicators. In contrast, Indicator 7 (making generalizations about the system) shows the lowest achievement in both classes; The control class only reaches ~49% and the experimental class is about 70%. This shows that although indicator 7 is still relatively low, the RWL approach is able to significantly increase the achievement of the indicator compared to control

Table 1. Comparison of the average posttest score (%) per system thinking skill indicator between the experimental and control classes.

Indicators	Short Description	Experiments (%)	Control (%)
1	Components & Processes	85%	53%
2	Simple Relationships	90%	63%
3	Dynamic Relationships	80%	56%
4	Component Organization	75%	57%
5	Flow of Matter & Energy	90%	61%
6	Hidden Dimensions	85%	60%
7	Generalization	70%	49%
8	Temporal Thinking	75%	57%

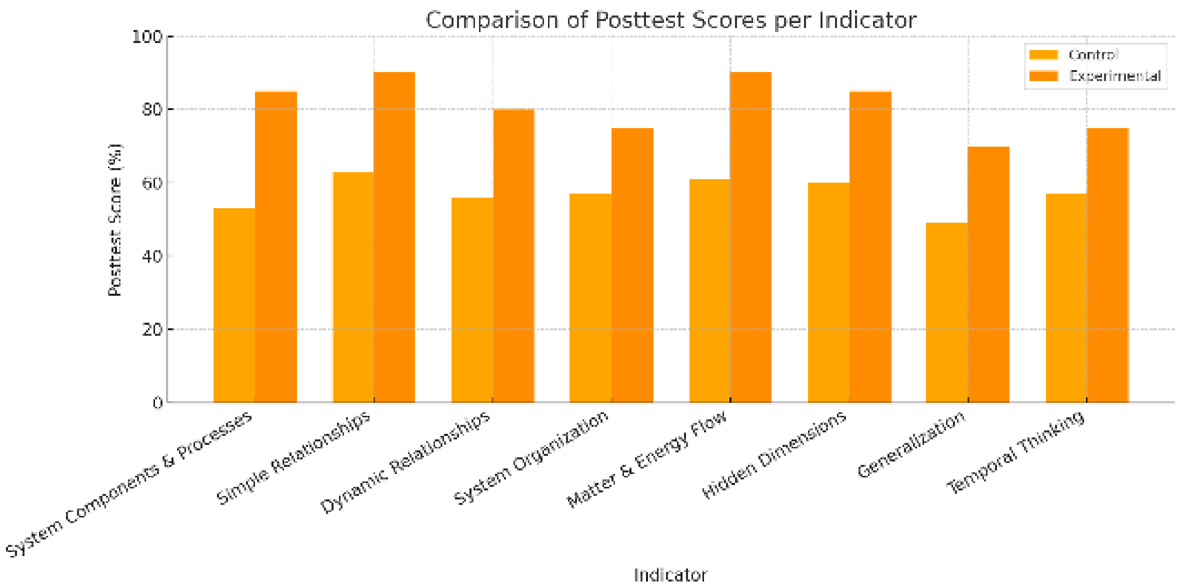

Figure 1. Posttest Score Comparison Chart

From the above results, the indicators with the highest scores after RWL treatment were indicators 2 and 5, where the experimental class achieved the highest score (close to 90%). These two indicators also experienced the highest increase compared to before the treatment, indicating that students were greatly helped by RWL learning in understanding the simple relationships between components and material/energy flows in the system. Meanwhile,

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the indicator that is still low after treatment is indicator 7 (generalization of the system). Although indicator 7 in the experimental class improved compared to the controls, the achievement was lowest (about 70% in the experiment). This may be because the ability to make generalizations is a high-level thinking skill that requires more intense practice. Indicator 4 (organizing components within a relational framework) and indicator 8 (temporal thinking) were also relatively low in achievement, indicating that these more complex aspects of systems thinking were challenging for students and required further deepening.

Overall, the experimental class showed a higher average N-gain (medium–high category, ~0.68) on all indicators than the control class with an average N-gain of about 0.30 (medium category). This confirms the effectiveness of the RWL approach in improving every component of system thinking skills. Effectiveness of SDG-6-based RWL: The findings per indicator above are in line with the contextual characteristics of RWL learning. In the experimental class, students learn the concept of environmental pollution through real world learning which is directly related to the SDGs-6 (Clean Water and Sanitation) issue. For example, students are given a case study of water pollution in the surrounding environment and are tasked with identifying causes, impacts, and solutions related to SDG-6 principles.

Differential Impact of SDG 6–Based Real-World Learning on Each Systems Thinking Indicator

Although the experimental group outperformed the control group across all eight systems thinking indicators, the degree of improvement varied between indicators, indicating that each component of systems thinking responds differently to the SDG 6–based Real-World Learning (RWL) approach. This variation reflects both the cognitive complexity of each indicator and the nature of the learning activities implemented.

Indicators related to simple causal reasoning and observable processes, such as identifying simple relationships between components (Indicator 2) and identifying flows of matter and energy (Indicator 5), showed the highest gains. This can be attributed to the direct experiential learning embedded in the RWL activities, where students observed water quality conditions, aquatic organisms, and pollution impacts firsthand. Such concrete experiences allow students to easily recognize linear cause–effect relationships, which aligns with prior research suggesting that real-world contexts strongly support early-level systems thinking development (Ben-Zvi Assaraf & Orion, 2005; Salsabila et al., 2024).

In contrast, Indicator 7 (making generalizations about the system) showed the lowest achievement despite improvement in the experimental group. Generalization requires students to abstract principles beyond a specific case and apply them to broader or unfamiliar contexts, which represents a higher-order cognitive demand. Many students were able to explain pollution phenomena in the observed water system but struggled to extend these explanations to other environmental or socio-ecological systems. This finding supports previous studies indicating that generalization is one of the most challenging components of systems thinking and requires repeated exposure to diverse contexts and explicit scaffolding (Mambrey et al., 2020).

Similarly, indicators involving dynamic and temporal reasoning (Indicators 3 and 8) showed moderate improvement but remained relatively challenging. While RWL activities facilitated understanding of immediate system changes, students had limited opportunities to model long-term system behavior or predict future consequences of pollution scenarios. This suggests that although SDG 6–based RWL effectively supports relational and structural understanding, additional instructional strategies such as system modeling, scenario simulation, or reflective discussions are needed to strengthen advanced systems thinking dimensions.

Overall, these results indicate that SDG 6–based RWL has a differentiated impact on systems thinking indicators: it is highly effective for developing concrete relational understanding, but less sufficient on its own for fostering abstract generalization and long-term system reasoning. This highlights the importance of aligning specific RWL activities with targeted systems thinking indicators.

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Potential Long-Term Impact of SDG 6–Based Real-World Learning on Systems Thinking

Beyond immediate posttest gains, it is important to consider the potential long-term impact of SDG 6–based Real-World Learning on students' systems thinking abilities. Although this study did not include a delayed posttest, several theoretical and empirical considerations suggest that the observed improvements may have enduring effects.

First, learning experiences grounded in real-world sustainability issues tend to promote deep conceptual understanding, which is more likely to be retained over time compared to decontextualized instruction. By engaging students directly with authentic environmental problems related to clean water and sanitation, RWL encourages meaningful learning and knowledge integration, both of which are key predictors of long-term retention (Lozano et al., 2017; Albareda-Tiana et al., 2018).

Second, systems thinking is inherently cumulative and develops progressively through repeated encounters with complex systems. The improvement observed in this study—particularly in relational and structural indicators—may serve as a cognitive foundation for more advanced systems reasoning in future learning contexts. Previous studies have shown that early exposure to systems-oriented learning can facilitate the transfer of systems thinking skills across domains when reinforced through continued practice (Ben-Zvi Assaraf & Orion, 2005).

However, the relatively lower achievement in indicators such as generalization and temporal thinking suggests that long-term sustainability of learning outcomes cannot be assumed automatically. Without continuous reinforcement, opportunities for abstraction, and explicit reflection, gains in higher-order systems thinking may diminish over time. Therefore, future research should incorporate longitudinal designs with delayed posttests to examine retention and transfer effects more comprehensively.

Despite this limitation, the integration of SDG 6 within RWL provides a strong pedagogical framework for sustainable learning. By situating science education within globally relevant and locally meaningful issues, SDG-based RWL has the potential not only to enhance short-term systems thinking performance but also to cultivate enduring sustainability competencies essential for lifelong learning and responsible citizenship.

4. CONCLUSION

Based on the findings of this study, Real-World Learning (RWL) integrated with SDG 6 (Clean Water and Sanitation) shows strong potential to enhance students' systems thinking skills in learning about environmental pollution. Students who participated in SDG 6–based RWL activities demonstrated higher posttest scores across all systems thinking indicators compared to those who experienced conventional instruction. The contextual and experiential nature of RWL appears to support students in understanding relationships, flows, and interactions within environmental systems more holistically.

However, these findings should be interpreted with caution due to several limitations. This study employed a quasi-experimental design with non-equivalent groups, which limits the extent to which causal conclusions can be drawn. Differences in prior learning experiences, classroom dynamics, and teacher facilitation may have influenced the observed outcomes. In addition, the relatively small sample size and short duration of the intervention restrict the generalizability of the results to broader educational contexts.

Despite these limitations, the results suggest that SDG 6–based RWL is a promising pedagogical approach for fostering systems thinking within nature-based education settings. Future research is recommended to apply experimental or longitudinal designs, involve larger and more diverse samples, and examine the long-term development of systems thinking skills. Such efforts would strengthen empirical evidence and further clarify the role of Real-World Learning in advancing Education for Sustainable Development.

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