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Radec Learning Model Boosts Scientific Process Skills And Sustainability Awareness In High-School Ecosystem Studies

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Abstract

This study examines the effect of the RADEC (Read-Answer-Discuss-Explain-Create) learning model on improving students' scientific process skills in ecosystem material and measuring students' sustainability awareness after the learning process. This study explores how the instillation of sustainability concepts after experiencing learning with the RADEC learning model impacts scientific process skills in science education. The research method used a single-class experiment. The results showed that among 33 high school students, there was a significant increase with a N -Gain of 0.51 (moderate criterion) in scientific process skills, with the highest Ngain of 0.74 on the classification indicator, supported by an average sustainability awareness score across three aspects: sustainability practice (3.18), behavioral and attitude awareness (3.43), and emotional awareness (2.98). This study highlights the potential of RADEC as an innovative pedagogical approach in fostering students' awareness of sustainability, and the use of the Read-Answer-Discuss-Explain-Create (RADEC) learning model has been proven to influence science literacy skills in ecosystem-related material with a Sig. (0.001) < 0.05 with the intensity of sustainability awareness at the "sometimes" response level.

Keywords: *RADEC learning model,Science process skills Ecosystem-environment, Student participation for suistainability awareness*

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INTRODUCTION

In the 21st century, the primary focus of the learning process is to develop skills such as critical thinking, problem-solving, metacognition, communication ability, collaborative ability, innovation and creativity, as well as information literacy (Mardhiyah et al., 2021; Idul & Caro, 2022). These competencies can flourish when scientific process skills are trained effectively within instruction (Khoiriah et al., 2023). Science process skills are the talents required to help students study science by empowering them to take ownership of their activities and actively solve problems (Putri & Nurwati, 2021). Science process abilities are crucial for learning implementation and can help prepare students for a world where science and technology are taking over (Jaya et al., 2022).

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As a result of its continued emphasis on science as a product and tendency to stress just cognitive components, science education today does not adequately cover all science process skills (Sholihah & Savitri, 2023). Jumaniar et al. (2024) claim that because Indonesian students continue to employ teaching strategies that are not KPS-equipped, their science process skills remain comparatively low. According to the findings of a study conducted at Multazam Junior High School by Wulandari et al., (2019) using questionnaires and interviews, kids' KPS remained comparatively low. According to another study, science process abilities in ecosystem material were comparatively low at SMPN Kota Sukabumi Class VII (Robiatul et al., 2020).

Science process skills are crucial in ecosystem learning because they teach students to observe biotic and abiotic components, categorize living things according to their roles, understand the relationships between components, and forecast the effects of environmental changes in addition to emphasizing conceptual mastery (Rahmat, 2024). Students are also instructed to use pertinent tools and materials to plan basic experiments, develop hypotheses, and pose critical questions (Syahrial et al., 2025). Presentations are then used to convey the findings of the study and apply them to the comprehension of environmental principles. Therefore, the use of KPS in ecosystem content can offer worthwhile educational opportunities, promote scientific thinking abilities, cultivate environmental awareness, and enhance problem-solving skills in the actual world.

Developing responsibility, 21st-century skills (such as critical thinking, literacy, scientific process skills, and collaboration), and encouraging real action to address global challenges are the objectives of sustainable learning. Sustainability awareness in the learning process is important because it not only equips students with an understanding of issues included in the objectives of education for sustainable development (ESD).

Subpar attempts to build and improve these skills during the learning process can result in low science process skills (Kusuma & Rusmansyah, 2022). Inadequate laboratory infrastructure and facilities are one of several causes causing low science process skills (Syarifudin, 2022). Teachers must therefore take into account a variety of alternative learning models that can be used to help students improve their science process abilities. Using a learning model approach, one of them is through enjoyable and significant learning experiences (Halim, 2022). According to Rahayu et al. (2024), the RADEC model is a type of innovative learning that may help students improve their science process abilities.

Read, answer, discuss, explain, and create are the steps that make up the RADEC learning paradigm, which is named after its syntax (Pratama et al., 2020). Every step of the RADEC learning approach enhances science process abilities. As they take in information from the teacher's texts or pictures, pupils in the Read stage hone their observational skills (Ramadhani & Muftianti, 2021). They then respond to pertinent questions in the Answer stage using the data grouping outcomes from the prior activity (Hasan et al., 2022). In order to improve their abilities to interpret, predict, and ask and answer questions, students then move on to the Discuss stage, where they talk about environmental issues that they have observed in their environment, the likely causes that have an impact on them, and workable solutions to stop pollution and climate change. When students submit their findings to the class during the Explain stage, the outcomes of these debates are conveyed (Ismayanti et al., 2022). Lastly, students integrate all of the KPS they have mastered in the Create stage by organizing modest experiments, developing hypotheses about solutions to environmental problems, and using tools and materials to create

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authentic work that demonstrates their comprehension of ecosystem ideas. As a result, the RADEC approach fully enhances students' science process skills while actively involving them in the learning process (Putri, Cindy & Zulfadewina, 2023).

Novelty and Contribution of This Study

While previous studies have explored the RADEC model in various contexts—such as RADEC-assisted by Canva media (Rahayu et al., 2024) and RADEC-based STEAM for science literacy (Putri, Cindy & Zulfadewina, 2023) this study offers distinct contributions. First, it specifically applies RADEC to ecosystem material, a topic requiring integrated observation, classification, and environmental reasoning skills that align uniquely with RADEC's syntax. Second, unlike prior research focusing solely on cognitive outcomes, this study bridges science process skills with sustainability awareness, addressing the urgent need to connect scientific competencies with environmental responsibility as outlined in Education for Sustainable Development (ESD) frameworks. Third, the study provides empirical evidence of RADEC's differential impact across science process skills indicators, revealing that observation and classification skills (N-Gain 0.71-0.74) respond more effectively to the model than higher-order skills like hypothesizing (N-Gain 0.41), thus offering nuanced insights for pedagogical refinement. Finally, this research contributes correlational evidence linking science process skills development to sustainability awareness, establishing a foundation for future interventions that simultaneously develop scientific competencies and environmental responsibility.

METHODS

This study employed a pre-experimental research design, specifically a one-group pretest–posttest design, to examine the effect of the RADEC model on students’ science process skills and sustainability awareness. This design was chosen because administering a pretest before the treatment allows the effects of the intervention to be determined more accurately by comparing the results with the pre-treatment condition. Table 1 below illustrates this design:

Table 1. One-group pretest-posttest design

Pretest	Intervetion	Postest
O1	X	O2

Notes:

O_1 = Initial measurement of science process skills

X = RADEC-based learning intervention (e.g., 4 sessions on ecosystem topics).

O_2 = Measurement after the intervention of science process skills and sustainability awarenes.

Sustainability awareness was measured only post-intervention due to the assumption of minimal prior structured education on the topic among participants, whereas science process skills—being highly dependent on individual competency were assessed pre- and post-intervention to isolate the RADEC model's impact. Sustainability awareness (especially attitudes/behavior) is often homogeneous among students before intervention (e.g., limited prior exposure to sustainability concepts in school curricula). Measuring it once post-intervention simplifies the design while still capturing the RADEC model's impact.

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Study Limitations

This study employs a one-group pretest-posttest design without a control group, which limits the ability to definitively attribute observed improvements solely to the RADEC intervention. Maturation effects, testing effects, or external factors cannot be entirely ruled out. Future research should incorporate a control group receiving conventional instruction or employ a matched-pairs design to strengthen causal inference. Additionally, random assignment and counterbalancing should be considered to minimize selection bias and order effects.

Participants

The participants consisted of 33 high school students (aged 15-16 years) from a public senior high school in West Java, Indonesia. Students were enrolled in Grade X and had not previously studied ecosystem material in detail. All participants provided informed consent, and parental consent was obtained for minors.

Instrumentation

1. Science Process Skills Test

The science process skills instrument consisted of 25 multiple-choice items covering nine indicators: observing (3 items), classifying (3 items), interpreting (3 items), predicting (3 items), asking questions (3 items), hypothesizing (3 items), planning experiments (2 items), using tools and materials (3 items), and communicating (2 items). Each item was designed to assess students' ability to apply specific KPS in the context of ecosystem concepts.

Validity and Reliability: The instrument was validated by three science education experts (Content Validity Index = 0.87) and piloted with 40 students not included in the main study. Cronbach's alpha reliability coefficient was 0.82, indicating good internal consistency. Item difficulty indices ranged from 0.30 to 0.70, and discrimination indices ranged from 0.35 to 0.65, confirming appropriate item quality.

Scoring Procedure: Each correct answer received 1 point, with total scores converted to a 0-100 scale. N-Gain scores were calculated using the Hake formula: N-Gain = (posttest score - pretest score)/(maximum score - pretest score), with categories: high ($\geq$0.70), moderate (0.30-0.69), and low (<0.30).

2. Sustainability Awareness Questionnaire

The sustainability awareness instrument comprised 25 Likert-scale items (1=Never to 5=Always) across three dimensions: Sustainability Practice Awareness (9 items, Cronbach's α=0.78), Behavioral and Attitude Awareness (8 items, α=0.81), and Emotional Awareness (8 items, α=0.76). The questionnaire was adapted from Yadav (2024) and validated through expert review and pilot testing with modifications to suit the Indonesian high school context.

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Data Collection Procedure

1. **Pre-test administration:** Students completed the science process skills test before any instruction on ecosystem topics
2. **RADEC intervention:** Four 90-minute learning sessions were conducted over two weeks, following the RADEC syntax:
   a. **Read:** Students read teacher-provided materials about ecosystems at home
   b. **Answer:** Students answered pre-learning questions individually
   c. **Discuss:** Small-group discussions on ecosystem issues and environmental problems
   d. **Explain:** Student presentations of group findings
   e. **Create:** Students designed posters or models demonstrating ecosystem concepts and sustainability solutions
3. **Post-test administration:** Students completed the science process skills test and sustainability awareness questionnaire

Data Analysis

Data were analyzed using SPSS version 26. Normality was assessed using the Shapiro-Wilk test. Since data were normally distributed ($p > 0.05$), paired t-tests were used to compare pretest and posttest science process skills scores. Effect size was calculated using Cohen's d. N-Gain scores were computed for overall science process skills and each indicator. Spearman's rho correlation was used to examine relationships between science process skills scores and sustainability awareness dimensions. Statistical significance was set at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Based on the pre-test-post-test single group research design that has been conducted, the data obtained provides a comprehensive picture of the effect of the RADEC (Read-Answer-Discuss-Explain-Create) learning model on improving students' scientific process skills in ecosystem material and measuring students' sustainability awareness after the learning process. This study also explores how the instilling of sustainability concepts after learning with the RADEC learning model impacts scientific process skills. The N-Gain scores can be seen in Table 2. below.

Table 2. N-Gain Values of Science Process Skills in Classrooms using the RADEC model

Kelas	Rata-rata Nilai		*N-Gain*	Kategori
	Pretest	*Posttest*		
Experiment	52	76	0,51	moderate
Control	53	71	0,39	moderate

Based on Table 2, the average pretest-posttest scores and N-Gain obtained show a change in science process skills by applying the RADEC model so that students can learn ecosystem material well. The average pretest scores obtained by students are still relatively low. This condition is due to the fact that they have not yet learned ecosystem material, so students answer questions based on their initial abilities. As explained by Erlita & Hakim (2022), students tend to experience difficulties when faced with questions related to concepts they do not yet understand, so they do not understand the meaning of the answers they write. Meanwhile, the average posttest scores show an increase in students' science process skills. After adopting the RADEC model to study, students were better equipped to respond to the posttest on ecosystem material. This is because the RADEC model can boost student engagement and promote in-depth comprehension of concepts because it follows a systematic learning pattern that starts with the reading, replying, discussing, explaining, and creating stages (Munjiah et al., 2024). The primary markers of science process abilities, such as observing, classifying, and communicating, were also taught to students through discussion and explanation (Wahyudi & Lazulva, 2021).

Statistical Significance of Improvements

Table 3. Statistical Analysis Results for Science Process Skills

Test Component	Statistic	Value	Interpretation
Normality Test (Shapiro-Wilk)	W-statistic (pretest)	0.951	$p = 0.134$ (normal distribution)
	W-statistic (posttest)	0.963	$p = 0.287$ (normal distribution)
Paired t-test	t-value	12.47	df = 32, $p < 0.001$***
	Mean difference	24.00	95% CI [20.13, 27.87]
Effect Size (Cohen's d)	d-value	2.17	Very large effect
N-Gain	Mean N-Gain	0.51	Moderate improvement

*Note: *** p < 0.001, indicating statistically significant improvement*

The statistical analysis confirms that the RADEC intervention produced highly significant improvements in science process skills ($t = 12.47$, $p < 0.001$). The large effect size (Cohen's $d = 2.17$) indicates that the magnitude of improvement is substantial and educationally meaningful, not merely statistically significant.

Improvement Science Process Skills by Indicator

Based on the findings from each assessment component, the improvement in science process abilities for each indication was examined. Table 4. below shows the average increase in science process skills for each indicator:

Table 4. Average Improvement in Science Process Skills Indicators

Science Process Skills Indicators	*Pretest*	*Posttest*	*N-Gain*	Criteria
Observe	54,41	86,76	0,71	High
Classify	54,90	88,24	0,74	High
Interpret	55,88	74,51	0,42	Moderate
Predict	54,41	74,26	0,44	Moderate
Ask questions	44,12	73,53	0,53	Moderate
Hypothesize	57,35	75	0,41	Moderate
Plan experiments	41,18	67,65	0,45	Moderate
Use tools and materials	55,88	73,53	0,40	Moderate
Apply concepts	47,06	70,59	0,44	Moderate
Communicate	47,06	75	0,53	Moderate
Average	**51**	**76**	**0,51**	**Moderate**

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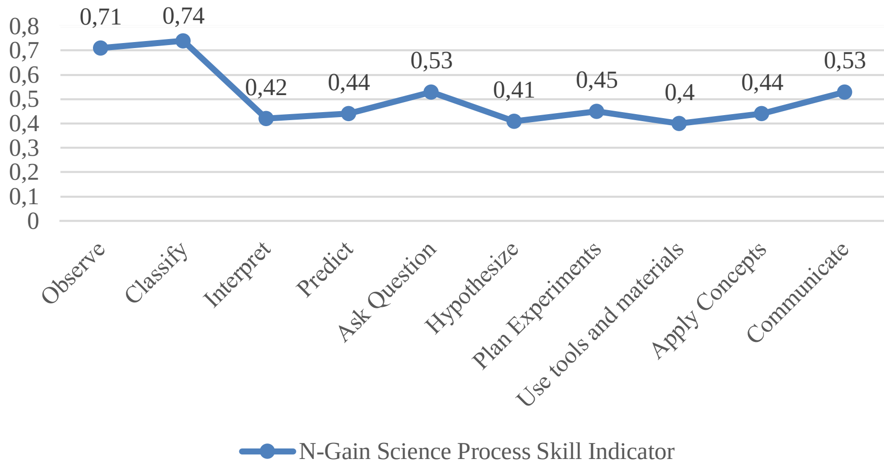
The following is a visualization of the N-Gain scores for each science process skill indicator, as shown in Figure 1.

Figure 1. Average Improvement in Science Process Skills Indicators



Based on Figure 1, the observation and classification indicators obtained a high N-Gain. This accomplishment is directly tied to the use of the RADEC learning paradigm, which gives students the chance to closely examine material through the Read and Answer phases of at-home pre-learning. Prior to in-person instruction, pupils in the Read stage analyze the content or problem stimuli that the teacher presents. In addition to improving reading literacy, this exercise improves visual and conceptual grouping and observational skills. According to research by Farahiba (2022), children who possess strong reading literacy abilities typically have an easier time comprehending, analyzing, evaluating, and interpreting the information presented in the text. According to research by Kusumaningpuri & Fauziati (2021), the RADEC learning model's Read stage can help students become better readers and observers while also helping them create new understandings based on the information they have learned.

Additionally, pre-learning questions that align with the indications help strengthen observation and classification abilities during the Answer stage. This is also demonstrated when teachers assign memory tasks, allowing students to identify and categorize biotic and abiotic elements, environmental interaction types, and pollution sources. Because students methodically group information or concepts before presenting them, they further refine their classification skills throughout the Discuss stage, which reinforces these abilities. According to Sopandi (2021), students participate in group conversations to share different approaches to problem-solving, which are then converted into multiple questions in the Discuss syntax of the RADEC learning paradigm. This supports Magfirah et al. (2024), assertion that the RADEC model's Discuss syntax can help students improve their conceptual grouping knowledge and thinking abilities. Students who participate in class discussions not only exchange knowledge but also gain the ability to categorize and contrast various concepts in order to comprehend how they relate to one another.

The moderate N-Gain values for higher-order science process skills indicators (hypothesizing, planning experiments, using tools) suggest that these skills require more intensive practice and scaffolding than

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the four-session intervention provided. Future implementations should consider extending the intervention duration or providing additional support for complex science process skills development.

Sustainability Awareness Outcomes

In addition to examining the effect of the RADEC (Read-Answer-Discuss-Explain-Create) learning model on improving students' scientific process skills in ecosystem material, this study also aims to measure students' sustainability awareness after the learning process. The visualization can be seen in Figure 2.

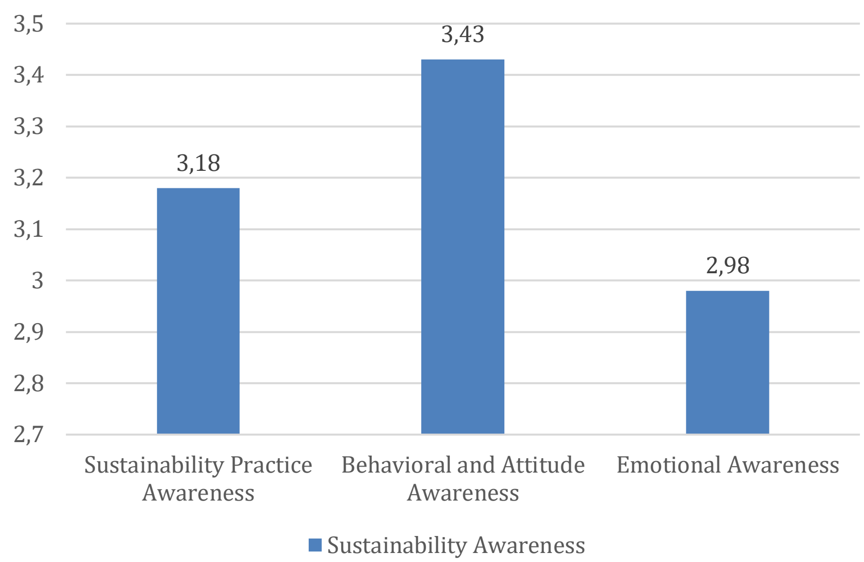

Figure 2. Sustainability Awareness

Figure 2 shows that the impact is not very significant, but in terms of behavioural and attitude awareness, sustainability practice awareness, and emotional awareness, the average score is sometimes (3). based on research (Yadav, 2024) The integration of sustainability into education is crucial for equipping individuals with the necessary knowledge, skills, and values to promote sustainable behaviors and address global challenges such as climate change and resource scarcity. This is because sustainability awareness requires time for familiarisation and implementation, which cannot be achieved in just one learning session. Sustainability awareness indeed requires time for familiarization and implementation, as highlighted in the paper. Sustainable learning is a gradual process that necessitates ongoing positive appraisals and motivational constructs to ensure deep learning. The authors emphasize that learning for sustainability, similar to language acquisition, involves implicit and explicit learning processes that develop over time, allowing individuals to internalize knowledge and adapt effectively to their environment. Thus, one learning session is insufficient for achieving lasting sustainability awareness (Schneider et al., 2013).The results of students' responses to sustainability awareness are presented in Table 5:

Table 5 Student Responses to Sustainability Awarness ***(Selected Items)***

Aspect	Code	Statement	Type	Student Response
Sustainability Practice	1	I practice the importance of protecting the environment in my daily life.	Positive (+)	**3 (Sometimes): 33.3%** **4 (Often): 33.3%**
	9	I consider the environmental impact of my purchasing decisions or daily activities	Positive (+)	**3 (Sometimes): 63.6%**
Behavioral and Attitude Awareness	12	I try to reduce the amount of waste at home by recycling	Positive (+)	**4 (Often): 30.3%**
	13	I turn on the lights at home during the day	Negative (-)	**5 (Never): 72.7%**
	17	I am thinking of plans to continue to raise awareness and improve behavior towards the environment in the future	Positive (+)	**4 (Often): 33.3%**
Emotional Awareness	19	I feel calmer and more peaceful when I am outdoors or close to nature.	Positive (+)	**5 (Always): 45.5%**
	20	I care about environmental issues in my home, especially those that contribute to global warming.	Positive (+)	**4 (Often): 42.4%**
	22	I feel that hot air makes me irritable.	Negative (-)	**1 (Always): 42.4%**
	23	I am aware of my responsibility towards the environment.	Positive (+)	**4 (Often): 42.4%**
Aspect	**Code**	**Statement**	**Type**	**Student Response**

According to the surve in table 4, students have a strong connection to nature and obviously care about the environment, but they don't always act on these sentiments on a daily basis. Many of them struggle to regularly avoid plastic bags, engage in activities, or select eco-friendly products, even when they are good at learning about concerns and are unhappy about pollution. To put it briefly, there is a discrepancy between what kids truly do and what they know and feel. The school should concentrate on making sustainable practices simpler and more interesting for all students in order to assist. The data reveals a significant awareness-behavior gap among the students. While they demonstrate strong emotional concern and positive attitudes toward environmental issues, this does not fully translate into consistent, high-frequency sustainable practices in their daily lives. Students are knowledgeable and care about the environment but face barriers to acting on these values consistently. Psychological barriers such as resistance to changing habits, lack of information on how to implement changes, and feelings of powerlessness are significant obstacles to sustainable behavior. Students often feel that their individual actions are insignificant compared to industry-caused environmental degradation, which can demotivate them from taking action (Mouchrek et al., 2023; Restya, 2022). Structural barriers, including convenience, cost, and lifestyle preferences, also hinder students from adopting sustainable practices. For instance, the availability and accessibility of green products can significantly influence students' ability to make sustainable choices (Danso & Owusuaa, 2024).

To better understand the overall trends in student perceptions, the mean Likert score for each survey item is presented in Figure 3:

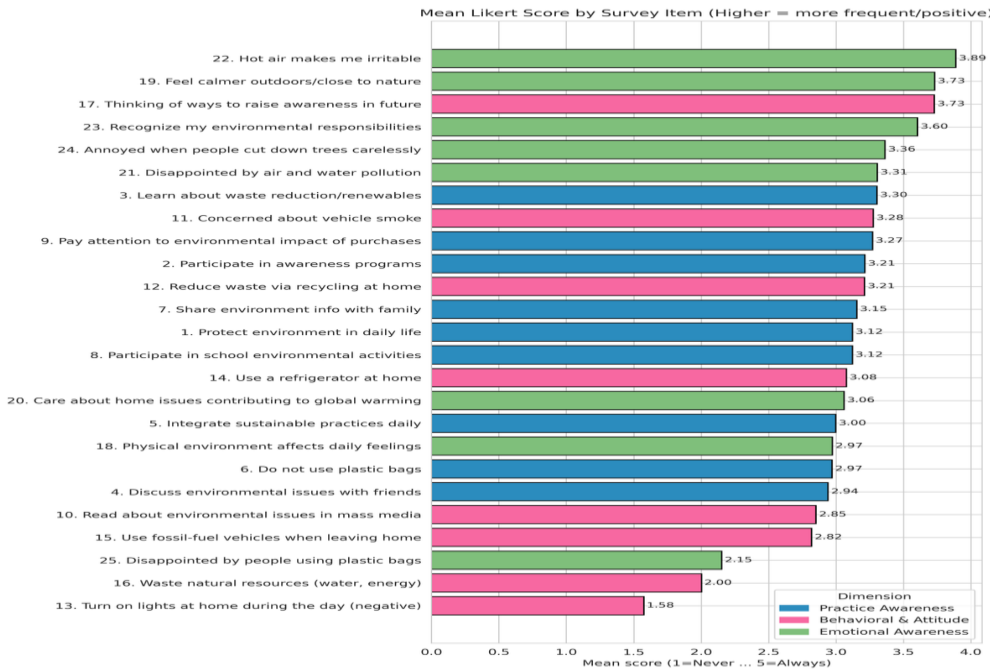

Figure 3. Mean Likert Score by Survey Item

Based on Figure 3, which shows the average Likert scale visualized through a chart, it can be simplified into the five highest statements with the highest average scores for statements Q22, Q19, Q17, Q23, and Q24, which emphasize sustainability emotions and attitudes characterized by a sense of individual responsibility.

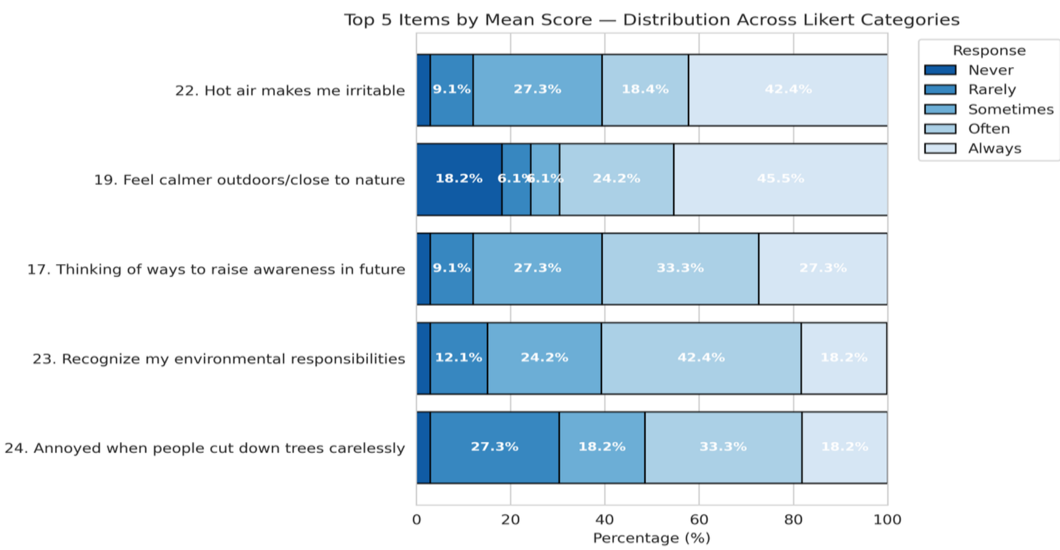

Figure 4. Top 5 Items by Mean Score

Based on the data from Figure 3, the findings show that respondents have strong emotional connections to environmental issues. Many feel irritated by hot air (Q22) and experience calmness when close to nature (Q19). They also think about ways to raise awareness in the future (Q17) and recognize

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their environmental responsibilities (Q23). Additionally, respondents feel annoyed when people cut down trees carelessly (Q24). Overall, these responses indicate a high level of awareness and concern for the environment, showing that people are mindful of their personal impact and the importance of sustainability.

Relationship Between Science Process Skills and Sustainability Awareness

Table 6. Correlation Between Science Process Skills and Sustainability Awareness

Variable	science process skills Post-test Score	Sustainability Practice	Behavioral Awareness	Emotional Awareness
science process skills Post-test Score	1.000	-	-	-
Sustainability Practice	0.423*	1.000	-	-
Behavioral Awareness	0.512**	0.678**	1.000	-
Emotional Awareness	0.387*	0.591**	0.643**	1.000

*Note: * p < 0.05, ** p < 0.01 (Spearman's rho correlation coefficients)*

Interpretation: Moderate positive correlations were found between science process skills scores and all three sustainability awareness dimensions, with the strongest relationship observed for Behavioral Awareness ($\rho = 0.512$, $p < 0.01$). This suggests that students who demonstrated higher science process skills also exhibited greater sustainability awareness, particularly in recognizing and intending to adopt sustainable behaviors.

The correlational analysis (Table 6) reveals moderate positive relationships between science process skills post-test scores and sustainability awareness dimensions ($\rho = 0.387$-0.512, $p < 0.05$), with Behavioral and Attitude Awareness showing the strongest association ($\rho = 0.512$, $p < 0.01$). This finding suggests that students who developed stronger scientific inquiry skills particularly observation, classification, and data interpretation—were also more likely to recognize environmental issues and express intentions toward sustainable behaviors.

This connection aligns with cognitive-behavioral theories suggesting that scientific thinking skills enable individuals to better understand complex environmental systems, perceive human impacts, and formulate evidence-based solutions (Yadav, 2024). The RADEC model's Discuss and Explain stages, where students analyzed ecosystem disturbances and proposed environmental interventions, may have served as bridges linking scientific competencies with environmental responsibility.

However, the moderate correlation strength (0.4-0.5 range) indicates that KPS development alone is insufficient for fostering high sustainability awareness. The awareness-behavior gap observed in Table 5—where students demonstrated strong emotional concern but inconsistent sustainable practices—suggests that structural, social, and psychological barriers (Mouchrek et al., 2023; Restya, 2022) moderate the translation of skills into action. Future research should investigate mediating factors (e.g., self-efficacy, perceived behavioral control) and test whether enhanced science process skills instruction combined with practical sustainability interventions yields stronger behavioral outcomes.

Sustainability of KPS Improvement and Retention

A critical question regarding the observed improvements is whether these gains persist over time. While the immediate post-intervention results demonstrate significant increases (N-Gain = 0.51, $p < 0.001$), the current study design does not allow for conclusions about long-term retention. Research on learning retention suggests that active learning approaches like RADEC, which emphasize student-centered activities and concept application, typically show better retention rates compared to passive instruction (Schneider et al., 2013). However, without delayed post-test measurements, we cannot determine whether the observed science process skills improvements represent durable skill acquisition or temporary performance gains.

The differential N-Gain values across science process skills indicators suggest that observational and classificatory skills (N-Gain 0.71-0.74) may be more readily consolidated into long-term memory than complex skills like hypothesizing (N-Gain 0.41). This pattern aligns with cognitive load theory, which posits that lower-complexity skills are more easily automated, while higher-order thinking requires sustained practice and deliberate scaffolding to achieve mastery (Sweller, 2011).

Future longitudinal studies should incorporate retention tests at 4-week and 8-week intervals post-intervention to assess the durability of RADEC-induced improvements. Such designs would reveal whether different science process skills indicators (e.g., observation vs. hypothesizing) demonstrate differential retention patterns, potentially informing instructional strategies for long-term skill development. Additionally, spaced practice sessions and periodic review activities could be integrated into curricula to enhance retention of both basic and higher-order science process skills.

Limitations and Future Directions

This study's findings should be interpreted considering several limitations:

1. **Design limitations:** The absence of a control group limits causal attribution; maturation, testing effects, or external factors cannot be entirely ruled out
2. **Temporal constraints:** The single post-test measurement of sustainability awareness does not capture developmental trajectories or behavior change over time
3. **Intervention duration:** The 4-session intervention may be insufficient for establishing habitual sustainable behaviors or fully developing higher-order science process skills
4. **Correlational nature:** The relationship between KPS and sustainability awareness is associative, not causal

We recommend future research to:

1. **Employ randomized controlled designs** with active control conditions (e.g., traditional instruction, alternative active learning models like PjBL) to establish clearer causal links
2. **Conduct longitudinal follow-up assessments** at 1-, 3-, and 6-month intervals to examine retention of KPS and sustainability behavior change
3. **Use mixed-methods approaches** combining quantitative assessments with qualitative interviews to understand mechanisms linking KPS to sustainability awareness

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4. **Investigate dose-response relationships** by varying RADEC implementation duration (e.g., 4 vs. 8 vs. 12 sessions) and intensity
5. **Examine mediating and moderating variables** such as environmental self-efficacy, perceived behavioral control, school support for sustainability, and socioeconomic factors
6. **Integrate practical sustainability activities** (e.g., school gardens, waste audits, community projects) alongside RADEC instruction to bridge the awareness-behavior gap

CONCLUSION

The improvement in scientific process skills of students who participated in learning using the RADEC model showed an N-Gain value of 0.51 with a moderate category for all indicators, but the observation and classification indicators were in the high category. Respondents showed moderate to high awareness (average ≈ 3.3/5) but inconsistent sustainable behavior (many answers were “sometimes/rarely”). The most positive attitudes were found in the Emotional Awareness dimension, while Practical Awareness (e.g., avoiding plastic bags, discussing the environment) received the lowest scores. Measuring sustainable awareness is not easy. Sustainability awareness needs to be done continuously and not just once in learning. The RADEC model is a learning method that can be applied to train individuals' independence in learning, starting with the reading stage, answering questions asked by the teacher who has facilitated with pre-learning questions, then conducting discussions that enable not only individual but also group learning to train social skills, then explaining the meaning in the process of student activities, where students are responsible for expressing their opinions on the results of the discussions, and the final stage, which is compiling ideas or concepts as a form of creativity built on the previous stages. Therefore, if the RADEC model is applied correctly, it will foster awareness of sustainability in the learning process.

REFERENCES

Danso, A. K., & Owusuaa, E. (2024). Exploring the Perspectives of Ghanaian Youth on the Sustainable Development Goals: Awareness, Attitudes, and Practice. *International Journal of Research and Innovation in Social Science*, *VIII*(X), 2573–2590. https://doi.org/10.47772/ijriss.2024.8100215

Erlita, & Hakim, D. L. (2022). Kesulitan Siswa Dalam Menyelesaikan Soal Segiempat Berdasarkan Kemampuan Berpikir Kritis Matematis. *Jurnal Educatio*, *8*(4), 1342–1350. https://doi.org/https:/doi.org/10.31949/educatio.v8i4.3513

Farahiba, A. S. (2022). Pengembangan Instrumen Tes Literasi Peserta Didik Pada Materi Teks Anekdot. *Jurnal Dimensi Pendidikan Dan Pembelajaran*, *10*(2), 146–154. https://doi.org/https://doi.org/10.24269/dpp.v10i2.4554

Halim, A. (2022). Pengaruh Model Read Answer Discussion Explain and Create (Radec) Pada Pembelajaran Tematik Terhadap Hasil Belajar Siswa Dimoderasi Motivasi Belajar. *Sosioedukasi : Jurnal Ilmiah Ilmu Pendidikan Dan Sosial*, *11*(1), 121–129. https://doi.org/https://doi.org/10.36526/sosioedukasi.v11i1.1950

Hasan, M., Maulidyanti, H., Tahir, M. I. T., & Arisah, N. (2022). Analisis Keterampilan Berpikir Kritis Peserta Didik melalui Kegiatan Literasi. *Jurnal Pendidikan, Sosial Dan Budaya*, *8*(2), 477–486.

e-ISSN: 2541-4135| p-ISSN: 1412-565 X

Idul, J. J. A., & Caro, V. B. (2022). Does process-oriented guided inquiry learning (POGIL) improve students' science academic performance and process skills. *International Journal of Science Education*, *44*(12), 1994–2014. https://doi.org/https://psycnet.apa.org/doi/10.1080/09500693.2022.2108553

Ismayanti, I., Tanjung, I. F., & Khairuddin, K. (2022). The Effect Of Predict-Observe-Explain (POE) Learning Model On Students' Science Process Skills Biology In MTs Aisyiyah Binjai. *Journal Of Education And Teaching Learning*, *4*(1), 25–37. https://doi.org/https://doi.org/10.51178/jetl.v4i1.441

Jaya, T. D., Tukan, M. B., & Komisia, F. (2022). Penerapan Pendekatan Inkuiri Terbimbing Untuk Melatih Keterampilan Proses Sains Siswa Materi Larutan Penyangga. *Educativo*, *1*(2), 359–366. https://doi.org/http://dx.doi.org/10.56248/educativo.v1i2.44

Jumaniar, J., Rusdianto, & Ahmad, N. (2024). Pengembangan E-Modul Berbantuan Flip Pdf Professional untuk Meningkatkan Keterampilan Proses Sains Siswa SMP. *Jurnal Basicedu*, *8*(2), 1095–1104. https://doi.org/https://doi.org/10.31004/basicedu.v8i2.7232

Khoiriah, S. U., Lubis, L. K. L. U., & Anas, D. K. N. (2023). Analisis Perkembangan Sistem Manajemen Pendidikan di Era Society 5.0. *Jurnal Ilmu Sosial, Pendidikan Dan Humaniora*, *2*(2), 117–132. https://doi.org/https://doi.org/10.56910/jispendiora.v2i2.650

Kusuma, A. E., & Rusmansyah. (2022). Practicality of the RODE Learning Model in Order to Improve Student Communication Skills. *International Journal of Recent Educational Research*, *3*(5), 616–630. https://doi.org/https://doi.org/10.46245/ijorer.v3i5.254

Kusumaningpuri, A. R., & Fauziati, E. (2021). Model Pembelajaran RADEC dalam Perspektif Filsafat Konstruktivisme Vygotsky. *Jurnal Papeda*, *3*(2), 103–111.

Magfirah, Imran, M. E., & Amal, A. (2024). Pengaruh Model RADEC (Read, Answer, Discussion, Explain, and Create) terhadap Kemampuan Berpikir Tingkat Tinggi. *Jurnal Riset Guru Indonesia (JRGI)*, *3*(3), 139–148. https://doi.org/https://doi.org/10.62388/jrgi.v3i3.454

Mardhiyah, R. H., Aldriani, S. N. F., Chitta, F., Zulfikar, & Rizal, M. (2021). Pentingnya Keterampilan Belajar di Abad 21 sebagai Tuntutan dalam Pengembangan Sumber Daya Manusia. *Lectura: Jurnal Pendidikan*, *12*(1), 29–40. https://doi.org/http://dx.doi.org/10.31849/lectura.v12i1.5813

Mouchrek, N. M., Cullen, C., Maunder, L., & Shaikh, T. (2023). Investigating environmental values and psychological barriers to sustainable behaviors among college students. *Consilience: Journal of Sustainable Development*, *26*. https://doi.org/10.52214/consilience.vi26.10153

Munjiah, A. U., Fajriani, M. H., Puspitasari, N. W., & Dewi, R. S. (2024). Model Pembelajaran RADEC sebagai Upaya Meningkatkan Evaluasi Pembelajaran HOTS di Sekolah Dasar. *Pendas : Jurnal Ilmiah Pendidikan Dasar*, *09*(04). https://doi.org/https://doi.org/10.23969/jp.v9i04.20610

Pratama, Y. A., Sopandi, W., Hidayat, Y., & Trihastuti, M. (2020). Pengaruh model pembelajaran RADEC terhadap keterampilan berpikir tingkat tinggi siswa sekolah dasar. *JINoP (Jurnal Inovasi Pembelajaran)*, *6*(2), 191–203. https://doi.org/https://doi.org/10.22219/jinop.v6i2.12653

Putri, Cindy, A., & Zulfadewina, Z. (2023). Pengaruh Model Pembelajaran RADEC berbasis STEAM terhadap Literasi Sains Siswa Kelas IV Sekolah Dasar. *Jurnal Elementaria Edukasia*, *6*(3), 1162–1170. https://doi.org/https://doi.org/10.31949/jee.v6i3.6280

Putri, N. C., & Nurwati, N. (2021). Pengaruh Laju Pertumbuhan Penduduk Berdampak pada Tingginya Angka Kemiskinan Yang Menyebabkab Banyak Eksploitasi Anak di Indonesia. *Jurnal Hukum Eksploitsi Anak*, 1–15. https://doi.org/https://doi.org/10.23969/humanitas.v3iI.2827

e-ISSN: 2541-4135| p-ISSN: 1412-565 X

Rahayu, A. S., Pratama, D. F., & Kelana, J. B. (2024). Upaya Meningkatkan Keterampilan Proses Sains: Model RADEC Assisted By Canva Media. *Action Research Journal Indonesia*, *6*(1), 1–12. https://doi.org/https://doi.org/10.61227/arji.v6i1.150

Rahmat, M. N. (2024). Pemanfaatan Model Pembelajaran Project Based Learning (PjBL) untuk Mengasah Kreativitas dan Meningkatkan Hasil Belajar Siswa pada Mata Pelajaran Dasar Pemrograman. *Jurnal Media Pendidikan Teknik Informatika Dan Komputer*, *7*(3), 17–22. https://doi.org/http://dx.doi.org/10.59562/mediatik.v7i3.4426

Ramadhani, L., & Muftianti, A. (2021). Pembelajaran Membaca Cepat Dengan Menggunakan Metode Survey, Question, Read, Recite, Dan Review Pada Siswa Kelas V Sd. *Creative of Learning Students Elementary Education*, *4*(6), 829–840. https://doi.org/https://doi.org/10.22460/collase.v4i6.5554

Restya, W. P. D. (2022). Understanding the Barriers Againts Eco-Friendly Behavior. *Jurnal Ecopsy*, *9*(2), 142. https://doi.org/10.20527/ecopsy.2022.10.011

Robiatul, L., Setiono, & Suhendar. (2020). Profil Keterampilan Proses Sains Siswa Kelas VII SMP Pada Materi Ekosistem. *Jurnal Ilmiah Pendidikan Biologi*, *6*(04), 519–525. https://doi.org/http://dx.doi.org/10.22437/bio.v6i4.10295

Schneider, H. D., Livitz, I. E., & Schneider, D. (2013). Sustainable Learning for Sustainability. *Journal of Organisational Transformation and Social Change*, *10*(2), 124–147. https://doi.org/10.1179/1477963313Z.0000000009

Sholihah, A. R. L., & Savitri, E. N. (2023). *Peningkatan Hasil Belajar Dan Keterampilan Proses Sains Materi Cahaya Dan Alat Optik Melalui Problem Based Learning Bagi Peserta Didik Kelas VIII*. 44–56.

Sopandi, W. (2021). *Model Pembelajaran RADEC (Teori dan Implementasi di Sekolah)*. UPI Press.

Syahrial, S., Juneda, J., Saskia, D., & Margaretha, D. (2025). Penggunaan Eksperimen Sederhana dalam Pembelajaran IPA di Sekolah Dasar: Tinjauan Pustaka. *Jurnal Bersama Ilmu Pendidikan (DIDIK)*, *1*(2), 81–86. https://doi.org/https://doi.org/10.55123/didik.v1i2.180

Syarifudin, M. (2022). Profil Keterampilan Proses Sains Siswa Kelas English Proficiency Program dan Reguler Materi Getaran dan Gelombang Dalam Kehidupan Sehari-Hari di SMP Muhammadiyah 2 Taman. *Academia Open*, *6*(1), 1–11.https://doi.org/https://doi.org/10.21070/acopen.6.2022.1750

Sweller, J. (2011). Cognitive load theory. In J. P. Mestre & B. H. Ross (Eds.), Psychology of Learning and Motivation (Vol. 55, pp. 37-76). Academic Press. https://doi.org/10.1016/B978-0-12-387691-1.00002-8

Wahyudi, D., & Lazulva. (2021). Analisis Keterampilan Proses Sains Siswa Melalui Pembelajaran Berbasis Proyek Pada Materi Larutan Elektrolit dan Non-Elektrolit. *Journal Education and Chemistry*, *3*(2), 49–57. https://doi.org/https://doi.org/10.36378/jedchem.v3i2.1872

Wulandari, P., Widiyawati, Y., & Sari, D. S. (2019). Pengembangan Lkpd Berbasis Nature of Science Untuk Meningkatkan Keterampilan Proses Sains. *Saintifika*, *21*(2), 23–34.

Yadav, S. (2024). Education for Sustainable Awareness With Integrating Eco Awareness Into Educational Curricula. *Practice, Progress, and Proficiency in Sustainability*, 103–122. https://doi.org/10.4018/979-8-3693-5748-4.ch006