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The effect of the RICOSRE learning model on science process skills, scientific literacy, and students' biology learning outcomes on biodiversity

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Abstract

The research is based on the low science process skills, science literacy, and student learning outcomes, which may hinder students' critical thinking, scientific reasoning, problem-solving, and decision-making skills required in 21st-century education. The RICOSRE (reading, identifying, constructing, solving, reviewing, extending) model was selected because it integrates reading literacy with systematic problem solving. The research aims to determine the effect of the RICOSRE model on science process skills, science literacy, and biology learning outcomes of students. The research uses a quasi-experimental non-equivalent control group design. The experimental class applies the RICOSRE model, the control class applies the Problem Based Learning model. Analyzed using normality tests, homogeneity tests, and hypothesis tests (ANCOVA). The results are N-Gain science process skills of the experimental class 46.91% (less effective), control class 21.49% (ineffective), a significance value <0.001 means there is a difference in influence between classes. N-Gain of the experimental class's scientific literacy skills was 40.80% (less effective), control class 29.26% (ineffective), a significance value <0.001 means there is a difference in influence between classes. N-Gain of the experimental class's learning outcomes was 38.02% (ineffective), control class 26.56% (ineffective) and a significance value of 0.004, meaning there is a difference in influence between classes. The conclusion the RICOSRE model generally has a positive impact on the research variables, but with varying levels of effectiveness in each variable.

Abstrak. *Penelitian ini didasarkan pada rendahnya keterampilan proses sains, literasi sains, dan hasil belajar siswa. yang dapat menghambat kemampuan berpikir kritis, penalaran ilmiah, pemecahan masalah, dan pengambilan keputusan siswa yang dibutuhkan dalam pendidikan abad ke-21. Model RICOSRE dipilih karena mengintegrasikan literasi membaca dengan pemecahan masalah secara sistematis. Penelitian untuk mengetahui pengaruh model RICOSRE (reading, identifying, constructing, solving, reviewing, extending) terhadap keterampilan proses sains, literasi sains, dan hasil belajar biologi siswa. Penelitian menggunakan eksperimen semu non-equivalent control group design. Kelas eksperimen menerapkan model RICOSRE, kelas kontrol menerapkan model pembelajaran berbasis masalah. Dianalisis dengan uji normalitas, uji homogenitas, dan uji hipotesis (ANCOVA). Hasilnya N-Gain keterampilan proses sains kelas eksperimen 46,91% (kurang efektif), kelas kontrol 21,49% (tidak efektif), nilai signifikansi <0,001 berarti adanya perbedaan pengaruh antarkelas. N-Gain kemampuan literasi sains kelas eksperimen 40,80% (kurang efektif), kelas kontrol 29,26% (tidak efektif), nilai signifikansi <0,001 berarti adanya perbedaan pengaruh antarkelas. N-Gain hasil belajar kelas eksperimen 38,02% (tidak efektif), kelas kontrol 26,56% (tidak efektif) dan nilai signifikansi 0,004, berarti adanya perbedaan pengaruh antarkelas. Kesimpulannya model RICOSRE secara umum memberikan dampak positif terhadap variabel penelitian, namun pada tingkat efektivitas yang berbeda pada masing-masing variabel.*

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A. Introduction

Learning 21st century emphasizes the development of competencies that enable students to adapt to rapid technological and social changes These competencies include critical thinking, problem solving, collaboration, creativity, communication, and scientific reasoning, which are essential for facing the challenges of the Industrial Revolution 4.0 and Society 5.0 (Sartini & Mulyono, 2022).

In line with these demands, the Merdeka Curriculum encourages student-centered learning that facilitates the development of knowledge, skills, and character through meaningful and contextual learning experiences. Educators need to strive to improve teaching methods that are in line with the demands of 21st century skills (Romlah et al., 2023; Susilowati, 2022).

In biology education, the demands of 21st-century learning are reflected in the need to develop science process skills, scientific literacy, and learning outcomes. Science process skills are physical and mental skills that should be owned by students in the learning process to acquire and develop knowledge that enable students to observe, classify, predict, communicate, and draw conclusions from scientific phenomena. Scientific literacy allows students to understand scientific concepts, evaluate evidence, solve real-life problems, and make informed decisions based on scientific reasoning. Scientific literacy competencies based on PISA are: explain phenomenon in a scientific way, evaluating and designing investigation scientific, interpreting data and evidence scientific. These competencies are closely related to biology learning because biological concepts are strongly connected to everyday life and environmental issues that require scientific understanding and problem-solving abilities. Learning outcomes is results the end that is owned participant learn after going through learning activities, one of the reasons measuring success or whether or not participants educate in learning and the success or failure of the learning process. Cognitive aspects and learning outcome indicators are: C1 (remember), C2 (understand, C3 (apply), C4 (analyze), C5 (evaluate), C6 (create). Learning outcomes can show with change behaviour that can observed between before and after activity learning, the study of a person's behavior is based on the level of knowledge of something that is studied and then known through tests (Bloom et al., 1956; Noviyanto et al., 2021; Wahyuningsih, 2020).

However, various studies and international assessments indicate that Indonesian students' scientific literacy remains relatively low. Scientific literacy is ability for understand scientific concepts and processes as well utilizing science to finish problem in life everyday life, scientific literacy in PISA is defined as capacity for use knowledge scientific, identifying questions, and interesting conclusion based on fact in frame understand natural the universe and the changes that occur due to human activities. The PISA results show that many students still experience difficulties in applying scientific concepts and reasoning to solve contextual problems (Ayu et al., 2025). This condition is supported by the findings of Afsani and Daud (2020), who reported that biology learning often focuses on conceptual understanding rather than the application of concepts through scientific processes.

A biology teacher at SMAN 2 Makassar, the learning challenges faced, including low student scientific literacy due to a lack of reading activities in class, a lack of meaningful understanding due to difficulty relating the material to everyday life, a lack of student activeness in asking questions, and unsatisfactory biology learning outcomes. And based on initial observations that were carried out by filling out an observation sheet by the observer and multiple-choice tests by students at SMAN 2 Makassar also revealed similar challenges. Students' science process skills were categorized as sufficient with a mastery level of 60%, scientific literacy was categorized as very low with an average score of 48.3, and biology learning outcomes were also very low with a mastery level of 49.7%. In addition, students showed limited participation in asking questions, difficulty connecting biological concepts with everyday life, and low engagement in reading activities.

These findings suggest that biology learning has not yet optimally facilitated the development of science process skills, scientific literacy, and learning outcomes expected in 21st-century education. Therefore, an instructional model that integrates literacy activities with problem-solving processes is needed. One learning model that has the potential to address these challenges is the RICOSRE model, developed by Mahanal and Zubaidah (2018) RICOSRE is an acronym from learning steps: (1) reading, (2) identifying the problem, (3) constructing the solution, (4) solving the problem, (5) reviewing the solution, and (6) extending the solution. RICOSRE integrates reading literacy activities with systematic problem-solving processes. Compared with Problem-Based Learning (PBL) steps: 1) orientation students on problems, 2) organize learners for study, 3) guide investigation individual and group, 4) develop and serve results work, 5) analysis and evaluation of fractional process problem, which directl engages students in problem-solving activities (Badriah et al., 2024; Sumiati et al., 2018).

Although the RICOSRE and PBL models are both based on contextual problem-solving, they differ in their taxonomic orientations and strategies for minimizing classroom problems. The main advantage of RICOSRE lies in its more systematic structure for guiding students' cognitive processes. Through its reading and extending syntax, RICOSRE successfully addresses the weaknesses of PBL, which often allows

students to jump directly into real-world problems without a strong conceptual foundation. The integration of literacy early in the reading phase in RICOSRE ensures a basic conceptual understanding before problem exploration begins. However, the rigidity of the RICOSRE syntax results in a significantly longer implementation time and a high initial cognitive load for low-potential students. Students who fail early on tend to lack confidence in progressing to the solution-building stage. In contrast, PBL offers greater flexibility by fostering student independence in utilizing various learning resources (such as libraries and the internet) and strengthening collaborative skills through group work. These collaborative advantages of PBL can theoretically address the individual anxiety often present in the RICOSRE model. However, PBL is prone to failure when implemented in classes with highly heterogeneous abilities due to the risk of unequal distribution of tasks, a situation RICOSRE can mitigate through its structured, individual problem-dentification phase (Haka et al., 2023).

Research relevant to this study includes: research by Mahanal and Siti (2017) which proved that the RICOSRE model was able to significantly improve students' cognitive learning outcomes and science process skills compared to conventional learning models. The structured syntax construction in RICOSRE was deemed successful in guiding students to hone their science performance skills. Furthermore, Zubaidah and Lestari (2016) found that the integration of reading literacy through the Reading stage at the beginning of the RICOSRE model became a crucial foundation that accelerated the understanding of abstract concepts in biology, thus having a positive impact on students' scientific literacy achievement. The effectiveness of RICOSRE was reinforced by the findings of Mahanal and Siti (2017) who compared the RICOSRE model with the PBL model, with the result that RICOSRE excelled in structuring students' logical thinking patterns because the solution-finding stages were carried out more gradually (step-by-step), which helped minimize student confusion compared to the flexibility of PBL. Although the RICOSRE model has great potential in the cognitive and scientific reasoning aspects, its implementation in the classroom is not without operational challenges, in line by the findings of Kurniawati (2022) which emphasize that the effectiveness of RICOSRE is highly dependent on the duration of student adaptation. Time constraints and the complexity of syntax often mean that improvements in scientific literacy and science process skills require long-term practice to achieve a highly effective level, especially for students who are not yet accustomed to independent learning.

Previous studies have reported that RICOSRE can improve higher-order thinking skills, critical thinking, and cognitive learning outcomes Nevertheless, studies examining its effect on science process skills, scientific literacy, and biology learning outcomes at the senior high school level are still limited, particularly in Makassar. Furthermore, the RICOSRE model has not yet been implemented in biology learning at SMA Negeri 2 Makassar. Therefore, this study extends previous research by investigating the effect of the RICOSRE model on these three variables in biodiversity learning.

Based on existing facts, previous relevant research, PISA data, and initial observations, this study was conducted to investigate the effect of the RICOSRE learning model on students' science process skills, scientific literacy, and biology learning outcomes in biodiversity learning. The RICOSRE model has never been implemented in high school biology instruction in Makassar City. The findings are expected to provide empirical evidence regarding the effectiveness of RICOSRE and contribute to improving the quality of biology learning in accordance with the demands of 21st-century education and the Merdeka Curriculum.

B. Material and method

The study used a quasi-experimental non-equivalent control group design. It was conducted in the odd semester of the 2025/2026 academic year at SMAN 2 Makassar. The experimental class applied the RICOSRE model, while the control class applied the Problem Based Learning model. The sample consisted of two classes: X.4 and X.10, with a total of 72 students. Purposive sampling technique was used considering that both classes had consecutive lesson schedules on the same day to minimize external bias, and based on their relatively similar average test scores and homogeneity. To ensure that differences in learning outcomes stemmed from the learning model applied, there was a control for external variables: classes were taught by the same teacher to avoid teaching style bias, classes took place during morning lessons to ensure equal student focus, classes received the same teaching materials, worksheets, as well as pre- and post-test questions. The research instruments used were science process skills observation sheets and multiple-choice tests to measure science literacy and learning outcomes. Data were analyzed descriptively and inferentially through normality, homogeneity, and hypothesis test with ANCOVA to control students' initial abilities with pretest scores as covariates using SPSS 27 at a significance level of 0.05. ANCOVA to prove whether the RICOSRE model has a real effect. N-Gain to measure how much improvement in practical. After obtaining data, is used Formula 1.

$$\text{N} - \text{Gain} = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Maximum Score} - \text{Pretest Score}} \ldots \text{Formula 1}$$

The effectiveness of the improvement in students' learning achievement was determined using the N-Gain effectiveness criteria presented in Table 1. This classification was used to identify the level of

effectiveness of the learning model implementation based on the percentage of students' score improvement. Students' science process skills observed during the learning activities were then categorized according to the criteria shown in Table 2. These categories were used to assess the level of students' proficiency in performing scientific process skills throughout the experim ental activities. Furthermore, students' scientific literacy test scores were interpreted using the scientific literacy classification shown in Table 3. This categorization helped determine students' level of understanding and ability to apply scientific concepts in solving contextual problems. In addition, students' cognitive learning achievement after the learning intervention was evaluated based on the learning outcome criteria presented in Table 4. This categorization was used to determine the overall level of students' academic performance after the implementation of the learning model.

Table 1 N-Gain effectiveness categories

Percentage (%)	Interpretation
0-40	Ineffective
41-55	Less effective
56-75	Enough effective
75-100	Effective

(Source: Baehaqi et al., 2024)

Table 2 Science process skills categories

Value interval	Category
81-100	Very skilled
69-80	Skilled
56-68	Quite skilled
44-55	Less skilled
0-43	Unskilled

(Source: Azwar, 2022)

Table 3 Scientific literacy skills categories

Value interval	Category
75-100	Very high
58-74	High
42-57	Sufficient
25-41	Low
0-24	Very low

(Source: Azwar, 2022)

Table 4 Learning outcome categories

Value interval	Category
90 – 100	Very high
80 – 89	High
65 – 79	Sufficient
55 – 64	Low
0 – 54	Very low

(Source: Azwar, 2022)

C. Results and discussion

The science process skills (SPS) of students in experiment (RICOSRE) and control (PBL) classes can be seen in Table 5. Table 5 shows that students' science process skills improved in both classes after the learning process. However, the increase in the RICOSRE class was higher than in the PBL class.

Theoretically, this increase in science process skills can be explained by constructivism theory, which states that knowledge is actively constructed by students through learning experiences and interactions with the environment. In the RICOSRE model, students are not only involved in problem-solving but also through the stages of Reading, Identifying the Problem, Constructing the Solution, Solving the Problem, Reviewing the Solution, and Extending the Solution. These stages provide students with opportunities to systematically engage in scientific activities such as observing, identifying problems, interpreting information, communicating results, and drawing conclusions. These activities align with indicators of science process skills, which include observation, classification, prediction, communication, and inference (Fitriani et al., 2019).

The findings of this study align with those of Mahanal et al. (2019), who stated that RICOSRE can empower students' thinking skills through a structured problem-solving process. This research is also supported by Senisum et al. (2022), who found that a learning model involving active scientific investigation can improve students' science process skills and learning outcomes. Furthermore, Sumiati et al. (2018) reported that RICOSRE syntax provides students with opportunities to construct knowledge independently, thereby improving the quality of the learning process.

These results indicate that RICOSRE's advantage over PBL lies in the Reading and Reviewing the Solution stages. These two stages help students gain conceptual understanding before solving problems and reflect on the solutions they have generated. In contrast, in the PBL model, students focus more on problem-solving, so learning success is highly dependent on their prior knowledge. Therefore, students with low initial abilities tend to take longer to achieve optimal science process skills. Therefore, students with low initial abilities tend to take longer to achieve optimal science process skills. Despite significant improvements, research results indicate that some students still have not reached the highly skilled category, particularly in PBL classes. This condition is thought to be influenced by students' limited experience in conducting scientific activities independently, learning habits that are still oriented towards memorization, and limited time for implementation. Furthermore, students are not yet accustomed to learning that requires active engagement in reading, analyzing, and evaluating information in depth. Furthermore, analyzed N-Gain of science process skills in experiment and control classes can be seen in Table 6.

Table 5 Frequency distribution and percentage of science process skills in RICOSRE and PBL model

Interval	Category	RICOSRE				PBL			
		O_1		O_3		O_1		O_3	
		F	%	F	%	F	%	F	%
81-100	Very skilled	0	0	14	38.9	0	0	3	8.3
69-80	Skilled	10	27.8	21	58.3	11	30.6	20	55.6
56-68	Quite skilled	15	41.7	1	2.8	13	36.1	10	27.8
44-55	Less skilled	11	30.6	0	0	11	30.6	3	8.3
0-43	Unskilled	0	0	0	0	1	2.8	0	0
Amount		**36**	**100**	**36**	**100**	**36**	**100**	**36**	**100**

Table 6 Analysis N-Gain SPS in RICOSRE and PBL models

Learning model	N-Gain (%)	Category
RICOSRE	46.9051	Less effective
PBL	21.4486	Ineffective

Table 7 Frequency distribution and percentage of scientific literacy ability in RICOSRE and PBL model

Interval	Category	RICOSRE				PBL			
		Pretest		Posttest		Pretest		Posttest	
		F	%	F	%	F	%	F	%
75-100	Very high	0	0	10	27.8	0	0	4	11.1
58-74	High	4	11.1	22	61.1	5	13.9	19	52.8
42-57	Sufficient	14	38.9	4	11.1	14	38.9	13	36.1
25-41	Low	18	50.0	0	0	17	47.2	0	0
0-24	Very low	0	0	0	0	0	0	0	0
Amount		**36**	**100**	**36**	**100**	**36**	**100**	**36**	**100**

Table 8 Analysis N-Gain scientific literacy skills in the RICOSRE and PBL models

Learning model	N-Gain (%)	Category
RICOSRE	40.8004	Less effective
PBL	29.2625	Ineffective

Table 9 Frequency distribution and percentage of cognitive learning outcome in RICOSRE and PBL model

Interval	Category	RICOSRE				PBL			
		Pretest		Posttest		Pretest		Posttest	
		F	%	F	%	F	%	F	%
90-100	Very High	0	0	0	0	0	0	0	0
80-89	High	0	0	7	19.4	0	0	4	11.1
65-79	Sufficient	5	13.9	16	44.4	4	11.1	12	33.3
55-64	Low	3	8.3	9	25.0	3	8.3	6	16.7
0-54	Very low	28	77.8	4	11.1	29	80.6	14	38.9
Amount		**36**	**100**	**36**	**100**	**36**	**100**	**36**	**100**

Table 10 Analysis N-Gain learning outcomes cognitive in the RICOSRE and PBL models

Learning model	N-Gain (%)	Category
RICOSRE	38.02	Ineffective
PBL	26.56	Ineffective

Table 11 ANCOVA test results on the effect of the RICOSRE and PBL learning model

Sources of variance	Dependent variable	Significance (p)	A	Hypothesis decision
Learning model (group)	Science process skills	<.001	0.05	H_1 accepted
	Scientific literacy skills	<.001	0.05	H_1 accepted
	Learning outcomes	.004	0.05	H_1 accepted

Table 6 shows that the improvement in students' SPS in the RICOSRE class falls into the "Less Effective" category, while the PBL class falls into the "Ineffective" category. There is a 25.46% difference in effectiveness, proving that the RICOSRE model is far superior in stimulating the development of students' SPS compared to PBL. This superiority confirms that the linear relationship between each scientific stage in RICOSRE and the SPS indicators is able to provide consistent stimulation for students to observe, classify, predict, communicate, and draw conclusions (Mahanal et al., 2025; Yuliskurniawati et al., 2021). The success of this investigative and reflective intervention is also supported by research by Siritheeratharadol et al. (2023) in the context of biology learning. However, the N-Gain score obtained which is still in the "Less Effective" category indicates practical limitations in the field. These barriers are strongly suspected to be triggered by students' limited initial experience with a fully investigative-based learning model, the complexity of RICOSRE syntax, which requires a longer adaptation period, and the relatively limited duration of classroom intervention. Therefore, this finding provides crucial scientific novelty to the existing literature: the effectiveness of field implementation of the RICOSRE model for KPS is highly dependent on students' initial readiness and the intensity of model familiarization in schools.

The scientific literacy ability of students in experiment and control classes can be seen in Table 7. Table 7 shows that students' scientific literacy skills in both classes improved after the learning process. However, the improvement in the RICOSRE class was higher than in the PBL class. In the RICOSRE class, most students who were initially in the low category moved to the high and very high categories after the learning process. The PBL class also experienced improvement, but the number of students reaching the very high category was still lower than in the RICOSRE class.

These findings indicate that the integration of reading and problem-solving activities in the RICOSRE model positively contributes to the development of students' scientific literacy. According to the OECD (2017), scientific literacy includes the ability to explain scientific phenomena, evaluate scientific investigations, and interpret scientific data and evidence. These abilities develop because students not only receive information but also analyze, evaluate, and apply it to problem-solving.

These research findings align with research by Hardianto et al. (2023), which found that implementing RICOSRE can improve students' information literacy through the integration of reading and reflective thinking activities. These findings also support Arifiyyati et al. (2022), who stated that the ability to analyze scientific information is a key component in developing scientific literacy. Furthermore, Ardianto and Rubini (2016) emphasized that scientific literacy develops when students are trained to understand, communicate, and apply scientific concepts in everyday life.

RICOSRE's advantage over PBL lies in the Reading stage, which provides a conceptual foundation before students encounter problems. Unlike PBL, which focuses directly on problem-solving, RICOSRE first builds initial understanding, making the analysis and evaluation process more meaningful.

Furthermore, analyzed N-Gain of scientific literacy skills in experiment and control classes can be seen in Table 8. In line with the SPS findings, the N-Gain results showed that the increase in scientific literacy skills in the RICOSRE class fell into the "Less Effective"

category, while the PBL class fell into the "Ineffective" category. However, the 11.54% difference in the N-Gain percentage emphasized the superiority of the RICOSRE model in facilitating mastery of complex biology material and contextual data interpretation. However, the less than optimal N-Gain achievement (which was stuck in the less effective category) reflects systemic challenges in the field. The low reading culture among students, the lack of initial experience in critically analyzing scientific texts, and the low level of basic scientific literacy capital of students during initial observations were suspected to be the main inhibiting factors. This study provides an important critical note: the great potential of the RICOSRE model in improving scientific literacy in the field requires the support of a school ecosystem capable of fostering sustainable literacy habits.

The cognitive learning outcomes in experiment and control classes can be seen in Table 9. Table 9 shows that students' cognitive learning outcomes in both classes improved after the learning process. In the RICOSRE class, most students who were initially in the very low category moved to the sufficient and high categories after the learning process. Meanwhile, in the PBL class, improvements also occurred, but most students remained in the very low and sufficient categories.

These improvements in learning outcomes indicate that problem-based learning can help students build conceptual understanding through active engagement in the learning process. However, the higher improvement in the RICOSRE class indicates that the integration of reading activities, problem analysis, reflection, and solution development provides additional benefits in building conceptual understanding.

These findings support research by Sumiati et al. (2018), which states that RICOSRE has the potential to improve students' cognitive learning outcomes through systematic learning stages. These findings also align with Mahmudah and Subiantoro (2025), who reported that RICOSRE can empower higher-order thinking skills, contributing to improved cognitive achievement. Furthermore, Zahra (2023) explained that metacognitive and reflective activities in biology learning play a crucial role in strengthening students' conceptual understanding and learning outcomes.

Theoretically, these results can be explained through constructivism theory, which emphasizes that knowledge is actively constructed through the process of elaborating information. The Reading stage helps students acquire initial information, the Constructing the Solution and Solving the Problem stages encourage students to connect concepts to real-world problems, while the Reviewing and Extending the Solution stages strengthen understanding through reflection and transfer of knowledge to new situations. Therefore, the learning process becomes more meaningful and contributes to improved learning outcomes.

Furthermore, analyzed N-Gain of learning outcomes in experiment and control classes can be seen in Table 10. Although the RICOSRE model consistently yielded cognitive outcomes superior to the PBL model (with a margin of 11.46%), the N-Gain analysis results for both classes fell into the "Ineffective" category. RICOSRE's structural superiority over PBL stems from PBL's inherent weaknesses in higher-order cognitive indicators, particularly at the C4 (Analyzing) level. Hestiana Rosana (2020) noted, PBL syntax often fails to perform optimally if students are not equipped with basic literacy skills before solving problems. PBL directly requires students to analyze complex problems independently (Baehaqi et al., 2024), while RICOSRE bridges this gap through an initial guided reading phase (Azrai et al., 2022). However, the "Ineffective" cognitive N-Gain score reveals significant practical limitations in practice. Students' low baseline abilities, a deeply rooted rote memorization culture in the classroom, and the broad scope of concepts in Biodiversity present significant challenges to short-term model optimization. These findings provide an important theoretical contribution to the world of education: statistical significance in experimental research does not necessarily reflect high practical effectiveness in the field. Full implementation of RICOSRE absolutely requires the support of external variables such as student readiness, adequate instructional duration, and early literacy skills development.

To test the significance of the influence of the learning model after being controlled by initial ability (pretest), an ANCOVA was carried out in Table 11. The learning model significantly influences students' science process skills, science literacy, and cognitive learning outcomes. The significance value for Science Process Skills and science literacy is < 0.001, while for cognitive learning outcomes it is p = 0.004. Because all significance values are much smaller than the value of $\alpha = 0.05$, the null hypothesis (H_0) is rejected and the research hypothesis (H_1) is accepted. These results empirically prove that there is a significant difference in influence between the implementation of the RICOSRE and PBL learning models on the three dependent variables after students' initial abilities are controlled. Comprehensively, these findings strengthen empirical evidence that RICOSRE is not only effective in triggering one aspect of competence, but is able to intervene in various interconnected dimensions of 21st-century competence (SPS, scientific literacy, and cognitive) in Biodiversity material at the high school level. The structured combination of strengthening functional literacy at the beginning (Reading) and providing objective evaluation space at the end (Reviewing) is the main distinction that makes RICOSRE much more adaptive and successful compared to conventional problem-based learning models such as PBL (Diani et al., 2023;

Mahanal & Zubaidah, 2018; Saputri, 2022; Yew & Goh, 2016).

This research makes an important contribution to the development of biology learning, particularly in the application of literacy- and problem-solving-oriented learning models. The results not only support previous research findings regarding the effectiveness of RICOSRE but also complement them by demonstrating that the model simultaneously impacts science process skills, scientific literacy, and learning outcomes in biodiversity material at the high school level. These findings provide an empirical basis for the integration of reading, problem-solving, and reflection activities into learning as an effective strategy to support the development of 21st-century competencies in students.

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D. Conclusion

Research shows that the RICOSRE model is superior to PBL in all three variables studied, with the highest increase in science process skills, due to the Reading stage that helps students build initial understanding before solving problems. The systematic syntax of RICOSRE supports meaningful biology learning, encourage active student involvement in the scientific thinking process, and shifts students' ability distribution from low to higher categories. Consequently, RICOSRE serves as a highly relevant alternative model for the Merdeka Curriculum to foster 21st-century competencies, including critical thinking, scientific literacy, and problem-solving. However, while ANCOVA analysis shows statistically significant differences, the N-Gain results reveal that the practical effectiveness remains in the less effective to ineffective category. Therefore, more optimal implementation strategies are required. Ultimately, these findings expand the study of RICOSRE at the high school level and provide a valuable reference for teachers designing student-centered, skill-oriented learning.

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