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Integrating RADEC model and classroom climate to enhance critical and collaborative skills in environmental change learning

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ABSTRACT

Critical thinking and collaborative skills are essential 21st-century competencies, yet many high school students still show limited development in these areas due to lack of conducive classroom environments and innovative learning models. This study aims to investigate the effects of the RADEC model and classroom climate on students' critical thinking and collaborative skills related to environmental change. A quasi-experimental design with a 2×2 factorial model was applied to 132 tenth-grade students selected through simple random sampling. Students were divided into experimental and control groups. The findings revealed that (1) the RADEC model significantly improved students' critical and collaborative thinking skills ($p < 0.001$), (2) classroom climate significantly affected these skills ($p = 0.001$), and (3) there was a significant interaction between the model and classroom climate ($p = 0.023$). These results indicate that integrating the RADEC model with a supportive classroom climate can effectively enhance students' 21st-century learning skills and provide practical insights for improving biology education.

INTRODUCTION

The 21st century, widely referred to as the era of globalization, scientific acceleration, and digital transformation, presents significant challenges for education systems worldwide. In this context, students are expected not only to acquire factual knowledge but also to master a set of higher-order competencies known as the 4Cs: critical thinking, collaboration, communication, and creativity (Fyolova et al., 2020; González-Sanmamed et al., 2020; Nithyanantham et al., 2020). These skills are considered fundamental for success in the workplace and society, as they enable learners to solve complex problems and adapt to rapid changes (Meyer & Norman, 2020). International assessments, however, reveal that many developing countries, including Indonesia, face persistent challenges in cultivating these skills. The Programme for International Student Assessment (PISA) 2022 reported Indonesia's average science literacy score as 382—substantially below the OECD average of 489—and its mathematics literacy score as 379 compared to the OECD average of 472 (OECD, 2023). These results reflect an urgent call for educational innovations that can bridge the gap between global demands and current learning practices.

At the national level, the Indonesian education system continues to face obstacles in realizing 21st-century competencies. Classroom practices remain dominated by rote memorization, limiting opportunities for analytical reasoning and collaborative learning (Ramadhan, 2023; Ratnasari & Nugraheni, 2024; Susongko et al., 2024). Although curriculum reforms, most notably the Merdeka Curriculum, emphasize student-centered approaches and the integration of higher-order thinking skills (Lestari & Hindun, 2023), their practical implementation often lags behind expectations. This mismatch between curricular goals and classroom realities has been highlighted as a key barrier to preparing students for global competitiveness. Within biology education, the challenge becomes even more pronounced as students are required to connect scientific concepts with pressing real-world issues such as climate change, biodiversity loss, and environmental degradation (Hanifah et al., 2021; Hidayanti et al., 2023). These issues demand not only cognitive understanding but also collaborative engagement to develop sustainable solutions.

Given these challenges, innovative pedagogical approaches are urgently needed. One such model is the Read–Answer–Discuss–Explain–Create (RADEC) learning model, designed to integrate cognitive and social dimensions of learning. RADEC encourages students to actively engage with texts, generate responses, discuss with peers, explain concepts, and create new products or ideas. Through these steps, students develop deeper comprehension, sharpen their critical thinking, and strengthen collaboration skills (Graesser et al., 2018). Previous research supports the potential of RADEC in enhancing critical and collaborative skills across various subjects (Kiska et al., 2024; Pratama et al., 2019). Based on Lubis et al. (2024) and Setiawan et al. (2022) also emphasize that RADEC aligns well with Indonesia's curricular demands by promoting student-centered learning and by leveraging accessible resources to foster active knowledge construction. These findings highlight RADEC as a relevant and timely approach for addressing the learning gaps faced by Indonesian classrooms.

Despite these advantages, the effectiveness of any pedagogical model cannot be separated from the classroom environment in which it is implemented. Classroom climate, defined as the socio-emotional and academic atmosphere of learning, plays a critical role in shaping student outcomes (Godfrey & Grayman, 2014; Wang et al., 2015). A supportive classroom climate fosters positive relationships, constructive interactions, and active engagement, all of which are conducive to the development of higher-order skills. Conversely, negative classroom climates, characterized by tension, lack of cooperation, or disengagement, often undermine students' motivation and limit their capacity to think critically and work collaboratively (Barr, 2016; Cheema & Kitsantas, 2016). Studies have demonstrated that classroom climate not only influences learning outcomes directly but also moderates the effectiveness of instructional strategies(Chang et al., 2021).

Previous studies on RADEC have generally confirmed its effectiveness in fostering cognitive and social competencies (Handayani et al., 2024; Kiska et al., 2024; Pratama et al., 2019). Separately, studies on classroom climate have established its significant role in shaping academic engagement, motivation, and problem-solving skills (Aizikovitsh-Udi & Cheng, 2015; Godfrey & Grayman, 2014), research combining these two dimensions remains scarce. Few studies have explicitly examined how RADEC, as a structured learning model, interacts with classroom climate to enhance both critical and collaborative skills, particularly within the domain of biology education on environmental change. The novelty of this study lies in its integrated approach to analyzing the effects of RADEC and classroom climate. While existing research has investigated these factors separately, this study focuses on their combined influence in the specific context of environmental change education in Indonesian high schools. This dual focus offers new theoretical contributions by exploring the interaction between pedagogy and learning environment, and practical insights for teachers seeking to optimize classroom conditions while applying innovative instructional models.

This research is urgent for several reasons. First, Indonesia's performance in international assessments highlights the immediate need to strengthen students' critical thinking and collaboration. Second, environmental change is a pressing global issue that requires scientifically literate and socially responsible citizens. Third, the implementation gap in the Merdeka Curriculum underscores the necessity of pedagogical innovations that are both feasible and effective. Together, these factors point to the significance of exploring the synergy between RADEC and classroom climate in order to empower students as future agents of change.

Although numerous studies have investigated the individual effects of the RADEC model and classroom climate, research that explores their combined influence remains limited—especially within the context of biology learning on the topic of environmental change. This topic holds strong real-world relevance and requires students to think critically and work collaboratively in analyzing environmental issues such as global warming, pollution, and ecosystem degradation (Hanifah et al., 2021; Hidayanti et al., 2023). Unfortunately, conventional teaching approaches often fail to connect these issues with students' personal contexts, resulting in suboptimal development of 21st-century competencies (Acim et al., 2024). Building on these considerations, this study aims to: (1) examine the effect of the RADEC learning model on students' critical thinking and collaborative skills; (2) analyze the effect of classroom climate on these skills; and (3) investigate the interaction between RADEC and classroom climate in shaping tenth-grade students' competencies in biology learning on environmental change topics.

METHODS

Research Design

This study employed a quantitative approach with a quasi-experimental design using a 2×2 factorial model (Creswell & Creswell, 2018). The participants consisted of 132 tenth-grade students from a senior high school in South Tangerang, Indonesia. Students were selected through simple random sampling and divided into two groups: an experimental class and a control class. The experimental class received instruction using the RADEC learning model, while the control class was taught using the Direct Instruction (DI) model. The use of RADEC was based on its potential to foster critical thinking and collaborative skills through structured problem-solving and collaborative learning (Lubis et al., 2024; Setiawan et al., 2022), whereas DI was chosen as a comparison because it represents a conventional teacher-centered method that is still commonly used in Indonesian classrooms (Rosyida et al., 2016). At the beginning of the learning process, students in both groups completed a classroom climate questionnaire to assess their perceived classroom environment, which was categorized as either supportive or unsupportive.

Population and Samples

The population in this study consisted of all tenth-grade students (Phase E) in the province of Banten, Indonesia. A multistage random sampling technique was used. First, the city of South Tangerang was selected purposively based on accessibility and relevance to the research. Next, Ciputat subdistrict was chosen using cluster random sampling. From the senior high schools in Ciputat, one school was selected through cluster random sampling, which had eight tenth-grade classes in total. Four classes were randomly assigned: two as the experimental group and two as the control group, with an average of 33 students per class, resulting in 132 participants. In the final stage, purposive selection was applied based on classroom climate scores. Students were divided into supportive and unsupportive classroom climate categories using the top and bottom 40% of scores from the classroom climate instrument. As a result, 52 students from the experimental group and 52 from the control group were selected, yielding a total of 104 respondents included in the data analysis. The demographic characteristics of the respondents are presented in Table 1.

Table 1.
Demographic Characteristics of the Respondents

Group	N	Classroom Climate Category
Experimental	52	Supportive (26), Unsupportive (26)
Control	52	Supportive (26), Unsupportive (26)
Total	104	–

Instrument

This study used three instruments, namely, the classroom climate questionnaire, critical thinking skills test, and the collaborative skills questionnaire. All instruments had been tested for both validity and reliability. The classroom climate variable was measured using a dichotomous-scale questionnaire referring to three main indicators developed by Shechtman (2006), with sub-indicators adapted from Zedan (2010), consisting of 34 statements (Table 2). The classroom climate instrument was validated using point-biserial correlation, yielding 34 valid items out of 40 ($r \geq 0.266$). Reliability testing with the Kuder–Richardson Formula 20 (KR-20) produced a coefficient of 0.93, indicating excellent internal consistency.

Table 2.
Mapping of Critical Classroom Climate Indicators and Test Items

Numb.	Indicator	Sub-Indicator		Items		Total
				Positive	Negative	
1	Relationship	1.1	Teacher-Student Relationship	1, 2, 5, 8, 9, 10	3, 4, 6, 7	10
		1.2	Student-Student Relationship	12, 13, 15, 18	11, 14, 16, 17	8
2	Personal Growth	2.1	Satisfication and Enjoyment	19, 21, 22	20, 23, 24	6
		2.2	Competitiveness	26, 28	25, 27	4
3	System Maintenance	3.1	Gender equality and Tension	34, 37, 39, 40	35, 36	6
Total				**19**	**16**	**34**

The critical thinking variable was assessed using an essay-based test developed according to six indicators proposed by Facione & Facione (2013), consisting of 8 questions (Table 3). The validity test using Pearson's product–moment correlation indicated that 8 items were valid while 7 were invalid ($r \geq 0.266$). Reliability analysis with Cronbach's alpha yielded a coefficient of 0.78, confirming acceptable internal consistency.

Table 3
Mapping of Critical Thinking Skills Indicators and Test Items

Numb.	Indicator	Sub-Indicator		Items	Total
1	Interpretation	1.1	Categorizing and Clarifying	1	1
2	Analysis	2.1	Checking Ideas and Reasoning	2, 3	2
	Evaluation	2.2	Assessing Source Credibility	4	1
		2.3	Assessing Argument Quality	5	1
3	Inference & Conclusion	3.1	Conclusions and Evidence Questions	6	1
4	Explanation	4.1	Presenting Arguments	7	1
5	Self-regulation	5.1	Self-Correcting	8	1
Total					**8**

Meanwhile, the collaborative skills variable was measured using a 4-point Likert scale questionnaire based on five indicators from (Miller et al., 1994) and various supporting items from (Ishak et al., 2002), consisting of 20 statements and administered through peer-assessment (Table 4). The validity test using Pearson's product–moment correlation showed that 20 items were valid and 4 items were invalid ($r \geq 0.266$). The instrument demonstrated good reliability, with Cronbach's alpha of 0.86.

Table 4
Mapping of Collaborative Skills Indicators and Test Items

Numb.	Indicator	Items		Total
		Positive	Negative	
1	Interpersonal Skills	1, 2	3, 4	4
2	Group Management	5, 6, 9	7, 8	5
3	Questioning Skills	12, 13	10, 11	4
4	Conflict Resolution	14	15, 16	3
5	Exposure	20	17, 18, 19	4
	Total	**9**	**11**	**24**

Procedure

The research procedure consisted of five main stages (Figure 1). 1) Preparation, 2) Implementation, 3) Data Collection, 4) Data Analysis, and 5) Conclusion.

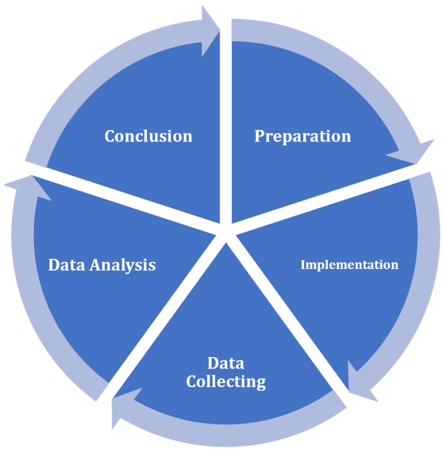


Figure 1. Procedure of the research

The first stage was preparation, during which teaching modules were developed for both the experimental and control groups. The experimental group used the RADEC learning model, while the control group used the Direct Instruction model. At this stage, instruments were also prepared, both test and non-test types, to measure the relevant variables. The second stage was implementation. It began with administering the classroom climate questionnaire to both the experimental and control classes. Following this, the experimental group underwent the learning process using the RADEC model, which was carried out in accordance with its structured syntax. During implementation, observations were conducted using teacher and student observation instruments. Meanwhile, the control group received instruction through the Direct Instruction model, following a conventional sequence. The third stage was data collection. After the instructional sessions concluded, data on students' critical thinking and collaborative skills were gathered from both the experimental and control groups. The final stages were data analysis and drawing conclusions. The collected data were analyzed using appropriate statistical techniques to determine the effects of the learning model and classroom climate on students' critical thinking and collaborative skills.

Data Analysis Techniques

The data analysis in this study included both descriptive and inferential statistical methods. Descriptive statistics were used to summarize and present the data in a comprehensible format without drawing conclusions for the population. Basic descriptive analysis provided information such as the mean, median, mode, and standard deviation of students' critical thinking and collaborative skill scores in both the experimental and control groups. Inferential statistics were applied to test hypotheses and make generalizations from the sample to the population.

The inferential analysis involved prerequisite tests and hypothesis testing. The prerequisite tests included: 1) Normality, using the Kolmogorov–Smirnov test at a significance level of $\alpha = 0.05$. If the p-value exceeded 0.05, the data were considered normally distributed. 2) Multicollinearity, it was assessed using the Variance Inflation Factor (VIF), with a VIF value ≥ 10 indicating multicollinearity. 3) Autocorrelation, using the Durbin-Watson test, where values between 1 and 3 were interpreted as indicating no autocorrelation. 4) Homogeneity of variance, it was tested using Box's M test, with p-values less than 0.05 indicating a violation of the homogeneity assumption. 5) Heteroskedasticity, it was evaluated using White's test, where a p-value greater than 0.05 suggested no evidence of heteroskedasticity. 6) A multivariate outliers test, using a scatterplot analysis (Box's M) was performed to visually examine deviations in the data distribution. Finally, hypothesis testing was conducted using Multivariate Analysis of Variance (MANOVA) with a significance level of α = 0.05. All statistical analyses were performed using JAMOVI version 2.6.2.

RESULTS AND DISCUSSION

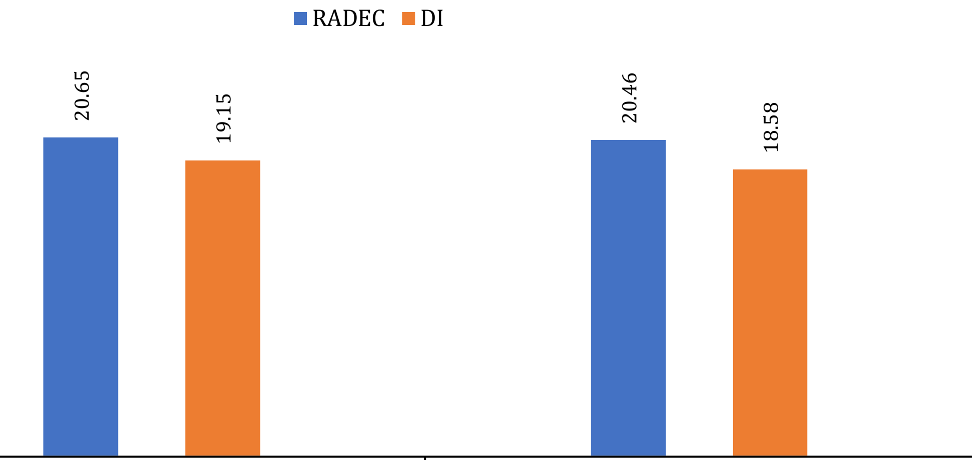
Based on descriptive statistics, it revealed significant differences in students' critical thinking (CT) and collaborative skills (CL) between the experimental and control groups. Descriptive statistics showed that students taught using the RADEC model achieved higher mean scores compared to those taught using the Direct Instruction model (Table 5). Descriptive statistics were used to compare students' critical thinking (CT) and collaborative skills (CL) across different groups. Table 4 presents the mean scores and standard deviations of students taught with the RADEC model and those taught with the Direct Instruction (DI) model, categorized by supportive and unsupportive classroom climates.

Table 5.
Descriptive statistics table

	RADEC				Direct Instruction			
	Supportive		Unsupportive		Supportive		Unsupportive	
	CT	CL	CT	CL	CT	CL	CT	CL
N	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00
Min	12.00	45.00	14.00	40.00	12.00	36.00	8.00	32.00
Max	31.00	80.00	30.00	59.00	27.00	60.00	25.00	58.00
Mean	20.65	51.65	20.46	50.58	19.15	49.88	18.58	48.38
St. Dev	4.73	9.55	3.65	4.27	4.26	5.36	3.63	4.93

As shown in Table 4, students in the RADEC group consistently achieved higher mean scores in both CT and CL compared to those in the DI group. This suggests that the RADEC model provides more opportunities for active discussion, problem-solving, and collaboration, which are aligned with the development of higher-order thinking skills (Graesser et al., 2018). Furthermore, the supportive classroom climate condition amplified these effects, reinforcing the notion that pedagogy and classroom environment interact to shape learning outcomes (Godfrey & Grayman, 2014). These findings are consistent with previous studies reporting that innovative models combined with supportive classroom climates foster critical and collaborative competencies more effectively than conventional approaches (Pratama et al., 2019; Chang et al., 2021).

From the histogram (Figure 2), it can be seen that learners with a supportive classroom climateand getting RADEC model learning treatment have an average score of critical thinking skills of 20.65, higher than the group with the DI model, which has an average score of 19.15. Meanwhile, students with unsupportive classroom climateconditions in classes with RADEC learning models obtained an average score of 20.46, while the DI group had a lower score of 18.58. When viewed based on classroom climate, supportive classroom climateconditions in each learning model also provide higher average scores than unsupportive classroom climateconditions. These results show that the RADEC learning model with supportive classroom climateconditions consistently produced higher average critical thinking skills than DI and unsupportive classroom climateconditions. This indicates that the RADEC model and supportive classroom climateconditions are more effective in developing critical thinking skills.



	CT in Supportive Classroom Climate	CT in Unsupportive Classroom Climate
RADEC	20.65	20.46
DI	19.15	18.58

Figure 2. Average critical thinking skills score

Overall, the average scores of students' critical thinking skills taught through both the RADEC and DI models were higher in supportive classroom climates compared to less supportive ones. This finding is consistent with the studies of Aizikovitsh-Udi & Cheng (2015) and Ilham S et al. (2020), which indicate that the RADEC model and a supportive classroom climate can positively influence students' critical thinking skills.

Critical Thinking Skills are tested using an instrument with a total of 8 questions and come from 6 indicators: 1) Interpretation, 2) Analysis, 3) Evaluation, 4) Inference and Conclusion, 5) Explanation, and 6) Self Regulation. Based on the results of the overall calculation according to Figure 2, the results of the largest percentage value in the Evaluation indicator are 24.6%, which is also almost the same as the Analysis dimension. Then in the Interpretation indicator, Inference & Conclusion indicator, and Explanation indicator, all three of which have a percentage score of 13%. In addition, in the lowest order in the percentage score is the Self-regulation indicator, which is 12%, which means that it also does not have a significant difference in percentage score compared to the order of the percentage score on the indicator that is at the same level above it. The RADEC model naturally stimulates higher-order thinking, particularly in the domains of analysis and evaluation. The syntax requires students to answer questions, engage in group discussions, explain their reasoning, and create products collaboratively, all of which promote analytical processing and evaluative judgment (Graesser et al., 2018). However, the results showed that the self-regulation indicator was relatively low (12%). This may be attributed to the fact that Indonesian students are more accustomed to teacher-directed learning and less trained in independent reflection. Moreover, the emphasis on completing group products in the Create phase may have limited opportunities for individual reflection and self-correction. These findings suggest that while RADEC effectively fosters analysis and evaluation, teachers should provide explicit opportunities for self-regulation, such as incorporating reflective journals, self-assessment rubrics, or structured peer-feedback. Such practices would help strengthen students' metacognitive awareness and balance the development of critical thinking skills (Kusuma et al., 2024).

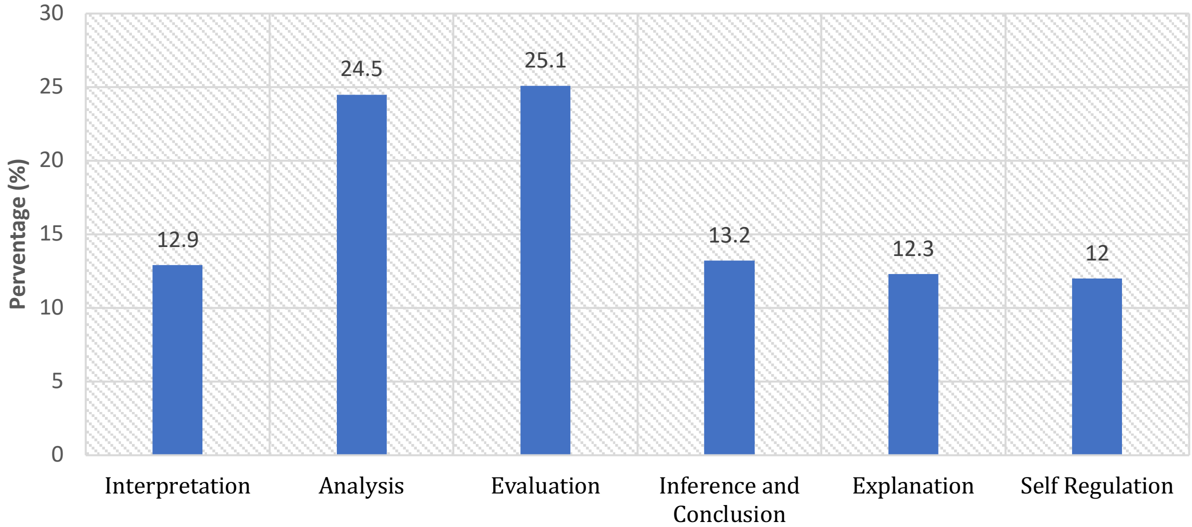
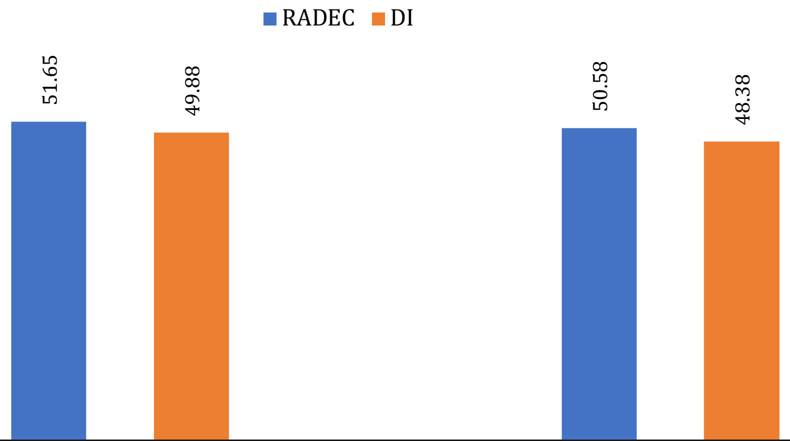


Figure 3. Critical Thinking Skills Indicator Score Percentage

From the histogram (Figure 3), it can be seen that students with a supportive classroom climateand treated with the RADEC learning model have an average score of 51.65 in collaborative skills, higher than the group with the DI model, which has an average score of 49.88. Meanwhile, students with unsupportive classroom climateconditions in classes with RADEC learning models obtained an average score of 50.58, while the DI group had a lower score of 48.38. When viewed based on classroom climate, supportive classroom climateconditions in each learning model also provide higher average scores than unsupportive classroom climateconditions. This indicates that the RADEC model and supportive classroom climateconditions are more effective in developing collaborative skills.



	CL in Supportive Classroom Climate	CL in Unsupportive Classroom Climate
RADEC	51.65	50.58
DI	49.88	48.38

Figure 4. Average collaborative skills score

Collaborative Skills are tested using an instrument with a total of 8 questions and come from 5 indicators. Based on the results of the overall calculation according to Figure 4, the largest percentage score is obtained in the Conflict Management indicator of 26%. Then in the Interpersonal Skills indicator of 21%. Followed by the Interpersonal Skills indicator of 20%. Furthermore, the Exposure indicator is 19%. Then the lowest score presentation result is in the Conflict Resolution indicator of 14%.

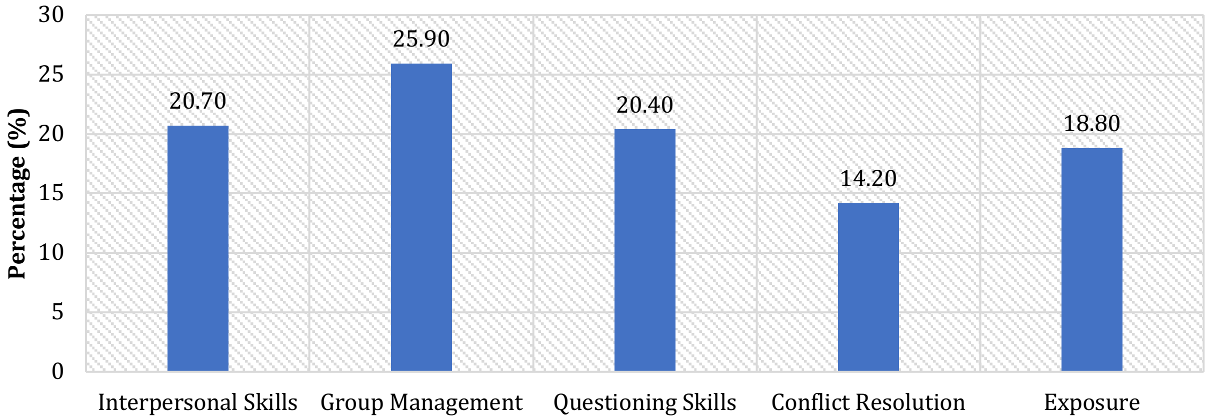


Figure 5. Collaborative Skills Indicator Score Percentage

To ensure that the data met the assumptions required for inferential analysis, several prerequisite tests were conducted before hypothesis testing. 1) The normality test using the Kolmogorov–Smirnov procedure indicated that the data were normally distributed, with p-values of 0.941 for critical thinking and 0.895 for collaborative skills, both exceeding the significance level of 0.05. 2) Multicollinearity was tested using the Variance Inflation Factor (VIF), with results showing VIF values of 1.00 for both variables, indicating no multicollinearity. 3) The Durbin–Watson test yielded a value of 2.27, which falls within the acceptable range (1–3), suggesting the absence of autocorrelation in the residuals. 4) Homogeneity of variance was confirmed using Box's M test, resulting in a p-value of 0.671, confirming that the variance-covariance matrices across groups were equal. 6) heteroskedasticity using the Breusch–Pagan test for heteroskedasticity showed a p-value of 0.891, indicating no homoscedasticity. Last, 6) Multivariate outlier inspection using Box Plot visualization showed no extreme data points, confirming the absence of outliers that might affect the integrity of the MANOVA (Figure 3).

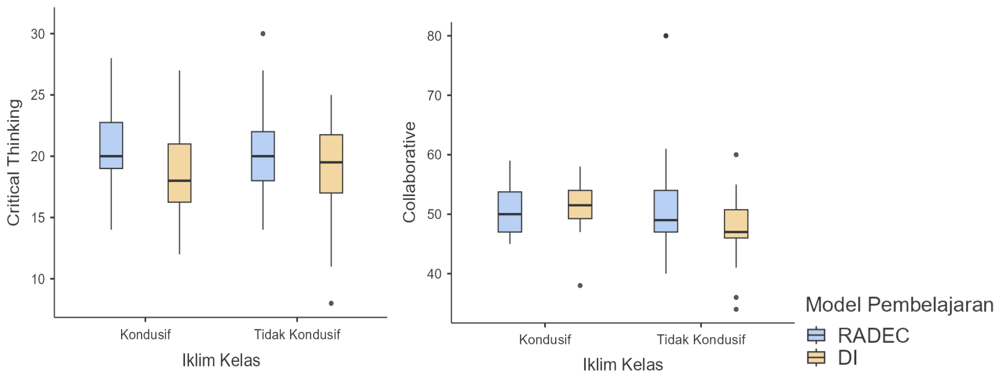


Figure 6. Graph of Multivariate Outlier Test Results

With all prerequisite assumptions satisfied, the next stage involved conducting MANOVA to test the influence of the learning model, classroom climate, and their interaction on students' critical thinking and collaborative skills. The results showed that the learning model had a statistically significant multivariate effect on the two dependent variables, as indicated by Wilks' Lambda. These results suggest that both the instructional approach and the psychosocial environment in the classroom contribute significantly to the development of students' 21st-century competencies, and their combined effect is particularly meaningful (Table 5).

Table 6.
MANOVA Test Result

	Test	P Value
Learning Models	Wilk's Lambda	< 0.001
Classroom Climate		0.001
Learning Models * Classroom Climate		0.023

The implementation of the RADEC learning model proved to have a positive effect on students' critical thinking and collaborative skills compared to the Direct Instruction model. This was evident from the higher average scores in the experimental class, as well as the students' active engagement in various stages of learning such as Answer, Explain, and Create. The "Answer" stage encouraged analytical thinking through case-based questions, while the "Explain" phase enabled students to express their critical thinking both verbally and in written form (Azisah et al., 2023; Ilham S et al., 2020; Sopandi, 2017). The "Create" stage invited students to produce work based on their reasoning and group collaboration, thereby strengthening their evaluative and reflective thinking (Rambe et al., 2025). This was reflected in dominant critical thinking indicators such as evaluation (24.6%) and analysis (24.4%) that appeared in students' responses. Other indicators, including self-regulation and inference, also emerged—albeit with smaller proportions—suggesting the need for more consistent reinforcement of individual reflection in the learning process (Permana et al., 2019).

Previous studies have reported that the RADEC model significantly enhances students' critical thinking skills (Azisah et al., 2023; Sopandi, 2017). Unlike these studies, which focused primarily on cognitive outcomes, the present research demonstrates that RADEC also strengthens collaborative skills, particularly in conflict management and group decision-making indicators. This finding highlights the dual impact of RADEC in fostering both higher-order thinking and social competencies, thereby extending the scope of its pedagogical effectiveness beyond what was previously documented.

In addition to critical thinking, the RADEC model also had a strong influence on students' collaborative skills. This was indicated by high scores on the conflict management indicator, which demonstrated students' ability to resolve differences of opinion constructively within group work (Badriyah et al., 2024; Cheruvelil et al., 2014). The "Discuss" and "Create" phases served as critical moments for developing collaboration, as students exchanged ideas, integrated perspectives, and produced shared outcomes. Another emerging collaborative skill was group management, evident through students' ability to listen to one another, divide roles fairly, and engage in meaningful dialogue.

The RADEC model clearly enhanced students' collaborative competencies through structured discussion and collective product creation, where idea exchange, conflict resolution, and shared decision-making occurred. The MANOVA results support the conclusion that RADEC has a simultaneous impact on both critical and collaborative skills due to its integrative, participatory, and 21st-century-oriented instructional characteristics. Nevertheless, the Direct Instruction model remains relevant for highly structured learning contexts that require strong teacher control, particularly for students who are not yet accustomed to active engagement (Candrawati, 2020; Maarif, 2020; Yanti, 2019). However, based on the findings of this study, RADEC is considered more adaptive to modern education and should be considered as an alternative learning model to comprehensively develop essential 21st-century skills.

The analysis showed that although the descriptive data between the experimental and control groups were relatively similar, a supportive classroom climatesignificantly influenced the enhancement of students' critical thinking and collaborative skills. A supportive classroom climateis characterized by strong teacher–student relationships, a supportive learning atmosphere, and healthy competition (Ferdiyanto & Muhid, 2020; Sari & Sukmawati, 2023; Sriklaub et al., 2015; Zedan, 2010) Sub-indicators such as Teacher–Student Relationship and Satisfaction & Enjoyment yielded high scores, highlighting the role of the teacher in fostering a comfortable and enjoyable learning environment (Çengel & Türkoğlu, 2016). Within such an environment, students feel safe to express their opinions, discuss ideas, and evaluate arguments—elements that serve as the foundation of critical thinking. Critical thinking indicators such as evaluation and analysis emerged prominently during this process, particularly as students engaged in the RADEC learning stages such as Answer, Explain, and Create, which demand higher-order and reflective thinking.

In addition, a supportive classroom climate also strengthened students' collaborative skills. Positive peer relationships, as reflected in the Student–Student Relationship sub-indicator, encouraged open interaction, effective cooperation, and constructive conflict resolution (Cadima et al., 2015). In the Discuss and Create stages of RADEC, collaboration was nurtured through shared discussions and co-creation activities, allowing students to practice communication, empathy, and team responsibility. The low scores on the Competitiveness indicator further supported this outcome, suggesting that the absence of negative competition created space for healthy collaboration (Ramakrishnan et al., 2019; Walker & Graham, 2021). Overall, the MANOVA results confirmed that a supportive classroom climatesignificantly contributes to the development of both critical thinking and collaborative skills. A supportive learning environment not only promotes student engagement but also serves as a foundation for cultivating meaningful thinking and high-quality teamwork in the context of 21st-century learning (Lu et al., 2021; Rahmi et al., 2017).

The results showed that the simultaneous implementation of the RADEC learning model and a supportive classroom climatesignificantly influenced the development of students' critical thinking and collaborative skills. This finding indicates that the advancement of these two essential 21st-century competencies is not solely determined by the learning model, but is also strongly affected by the classroom atmosphere. The RADEC model, with its structured syntax (Read, Answer, Discuss, Explain, Create), is designed to encourage active thinking, critical evaluation of information, and effective teamwork (Abidin et al., 21 C.E.; Hanum et al., 2023; Hernita & Dharma, 2023; Setiawan et al., 2022). The Discuss and Create phases specifically require students to express opinions, examine arguments, and make joint decisions, which reflect critical thinking indicators such as analysis and evaluation, while also reinforcing collaborative indicators such as active contribution and collective decision-making.

The success of RADEC in building these two skill sets becomes more optimal when implemented within a positive classroom climate—characterized by emotional safety, mutual respect, and open communication. Such an environment allows students to share their thoughts without fear of criticism, listen to others with empathy, and build healthy relationships within group work. In this context, critical thinking does not develop in isolation, but is actualized through meaningful social interactions. Likewise, collaboration becomes more meaningful when it occurs within an emotionally supportive setting. These findings underscore that the success of learning is not solely dependent on the instructional model used, but also on how well teachers establish a conducive classroom climate so that both critical and collaborative skills can grow in an integrated and balanced manner.

CONCLUSION

Implications of the findings of this study is the RADEC learning model has a significant effect on the critical thinking and collaborative skills of tenth-grade senior high school students in the topic of environmental change. In addition, the classroom climate condition also significantly influences the development of both skills. Furthermore, there is a significant interaction between the RADEC learning model and classroom climate, indicating that the integration of a structured learning model with a supportive classroom environment can optimally enhance students' critical thinking and collaborative competencies. These results highlight the importance of combining pedagogical approaches with positive psychosocial conditions to foster 21st-century skills in students.

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